ANL/EES-TM-270, Vol. 2

Movement of Tagged Dredged Sand at Thalweg Disposal Sites in the Upper Mississippi River

Volume 2: Savanna Bay and Duck Creek Sites

R. A. Paddock and D. L. McCown

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VOLUME 2: SAVANNA BAY AND DUCK CREEK SITES

by

R.A. Paddock and D.L. McCown

Energy and Environmental Systems Division
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FOREWORD

Argonne National Laboratory and the U.S. Army Corps of Engineers, Rock Island District, have undertaken a four-year investigation of main-channel, or thalweg, disposal of sand dredged during maintenance of the navigation channel in the Upper Mississippi River. During a routine dredging operation, hydraulically dredged sand was tagged with dyed sand and returned to the river channel downstream of the dredging site. The tagged dredged sand initially formed a pile along the thalweg of the river. The movement of the tagged sand in the river was monitored by taking surficial bottom samples and measuring bathymetry.

In a series of preliminary studies, Argonne evaluated alternative sampling and detection procedures for identifying tagged sand in the river environment. These preliminary studies were discussed in *Sampling and Detection of Tagged Dredged Material* (ANL/EES-TM-169), which was published in January 1982.

A full-scale experiment was first carried out in the fall of 1981 during a routine dredging operation at a site near Gordon's Ferry, about 23 km downstream of Dubuque, Iowa. Experience gained at this first site was used to refine the experimental procedures, and a second experiment was initiated at the Whitney Island site near Hannibal, Missouri, in the fall of 1982. The experimental procedures and the results from surveys at these first two sites through June 1983 were discussed in ANL/EES-TM-270, Vol. 1.

A third experiment using a dyed sand tracer was initiated at the Savanna Bay site near Savanna, Illinois, in the fall of 1983. In addition, bathymetric measurements were carried out at a fourth thalweg disposal site near Duck Creek, about 24 km upstream of the Savanna Bay site, to monitor changes in the physical structure of the disposal pile. The results from surveys at these second two sites over a nine-month period are presented in this volume (ANL/EES-TM-270, Vol. 2). Results from additional surveys at Gordon's Ferry and Whitney Island through the fall of 1984, including results from the analysis of bottom cores taken at the Gordon's Ferry site during the summer of 1983, will be reported in ANL/EES-TM-270, Vol. 3.

ACKNOWLEDGMENTS

The authors acknowledge the valuable assistance of Conrad Tome of the Energy and Environmental Systems Division (EES), Argonne National Laboratory, in carrying out the field experiments and in subsequent data analysis. John Ditmars, Section Leader, Geophysics and Engineering, EES, was instrumental in formulating the initial experimental objectives and providing guidance for the field operations.

The support provided by the Rock Island District of the U.S. Army Corps of Engineers exceeded simply funding the project. Henry Pfiester, Chief of Operations, participated in formulating the initial experimental plans and saw to it that we had access to logistical support from the District. Richard Baker, Chief of Channel Maintenance, Operations, often joined us in the field and provided valuable information regarding local river conditions. George Wells, the present project manager, was always available to provide an interface to groups within the Corps when their assistance was needed. The Survey Branch provided charts and established survey controls, and the Hydraulics Regulation Branch supplied the water level and flow data. Finally, the project would not have been possible without the assistance and patience of the Master and crew of the dredge *William A. Thompson* during the tagging operation.

The progress of this research was reviewed regularly by two units of the Great River Environmental Action Team: the River Resources Coordinating Team, chaired by George Wells of the District, and the On-Site Inspection Team, chaired by Gail Peterson of the U.S. Fish and Wildlife Service. Their questions, comments, and support are appreciated.

MOVEMENT OF TAGGED DREDGED SAND AT THALWEG DISPOSAL SITES IN THE UPPER MISSISSIPPI RIVER

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ABSTRACT

Experiments were conducted on the Upper Mississippi River at two sites, Savanna Bay and Duck Creek, to investigate the movement of dredged sand after disposal in the thalweg. These experiments are part of a larger study, which includes similar experiments conducted earlier at two other sites on the Upper Mississippi River. At the Savanna Bay site, hydraulically dredged sand was tagged with sand coated with fluorescent dye before being deposited as a pile in the thalweg. Bathymetric surveys and surficial bottom sampling were conducted on five occasions over a nine-month period following disposal to identify changes in the topography of the pile and to detect the presence of dyed sand. At the Duck Creek site, only bathymetric surveys were conducted.

The general behavior of the disposal piles at these two new sites was similar to that of the piles at the first two sites. Topographic evidence of the piles disappeared, and bottom conditions similar to the predisposal conditions were reestablished following the first period of high river flows after disposal. At Savanna Bay, as had happened at the first two sites, the tagged sand remained in the main river channel as it moved downstream in response to flood currents and did not migrate into nearby border areas, backwaters, or sloughs.

1 INTRODUCTION

Argonne National Laboratory has conducted several large-scale field experiments on the movement of dredged sand, after disposal, in the Upper Mississippi River. Hydraulically dredged sand was removed from the river during routine channel maintenance, tagged with dyed sand, and deposited as a pile in the main channel, or thalweg, downstream of the dredging site. The movement of the tagged sand in the river subsequent to disposal has been the focus of an ongoing study for the Rock Island District of the U.S. Army Corps of Engineers. The initial phases of the study, which were carried out at sites at Gordon's Ferry and Whitney Island, were reported in a previous volume.[1] Results from measurements taken over a nine-month period at two other sites, Savanna Bay and Duck Creek, are reported here. At Savanna Bay, the experiment involved tagging with dyed sand. At Duck Creek, bathymetric measurements alone were used to monitor the behavior of the disposal piles in the thalweg.

1.1 BACKGROUND

The Rock Island District has been investigating thalweg disposal as one option for disposing of uncontaminated sand dredged during maintenance of the nine-foot navigation channel in the Upper Mississippi River.[2] Thalweg disposal involves dredging sand from the shallow or shoal areas of the channel and disposing of it in deep water at another location along the channel.[3] Other disposal options include creating or nourishing beaches at the shoreline, piling sand on river islands, and placing the sand in upland locations out of the floodplain.[4,5] Environmental concerns regarding potential losses of aquatic and terrestrial habitats are common to all of the above options. Thalweg disposal appears attractive to the District in some instances because, in addition to low costs and minimal operational problems, habitat disruption may prove to be small.

Because the dredged sand is introduced back into the river in deep areas of the main channel, sensitive habitat regions, such as main-channel border areas, sloughs, and shallow backwaters, are not modified immediately upon disposal. However, the potential for subsequent movement of the dredged sand out of the main channel into sensitive habitats remains a concern. In addition, the main-channel habitats themselves may be affected, depending on the length of time the dredged sand remains as a pile in the thalweg.

An experimental procedure to tag dredged sand with sand coated with fluorescent dye and to track the tagged dredged sand in the surficial bottom sediments after disposal in the thalweg was developed by Argonne and the Rock Island District. After several small-scale tests, the procedure was implemented in October 1981 at Gordon's Ferry, about 23 km (14.3 mi) south of Dubuque, Iowa, as part of a normal channel-maintenance dredging operation. Experience gained at this site was used to refine the experimental procedure and to demonstrate the usefulness of the technique. A second experimental site with different characteristics was established in September 1982 at Whitney Island near Hannibal, Missouri. The experimental procedure and the results from these two sites through mid-1983 have been reported in ANL/EES-TM-270, Vol. 1.[1]

The general pattern of behavior of the dredged sand after disposal was the same at both sites. Little downstream movement was detected until periods of high river discharge (flooding) occurred. In response to these large discharges, the dredged sand was apparently mobilized along with other bed material and moved downstream in the main channel. The bathymetric identity of the disposal piles seems to have disappeared after such major discharge events, and the tagged sand appears to have been incorporated into bedforms in the main channel.

No evidence has been found of coherent movement of dredged sand directly into sensitive areas such as main-channel borders, backwaters, and sloughs. In fact, little evidence has been found of dredged sand being transported out of the main channel, as only a few grains of dyed sand have ever been found in nearby border areas or sloughs.

The experiments at Savanna Bay and Duck Creek were undertaken by the District to gain additional information concerning the movement of tagged sand from another thalweg disposal site and to investigate some environmental consequences of thalweg

disposal. Generally concurrent with the physical studies by Argonne reported here, the U.S. Fish and Wildlife Service conducted fish population and other studies for the District in the vicinity of these sites. Site selection was influenced by the results of the previous tagged sand experiments and the objectives of the U.S. Fish and Wildlife Service studies. The approach to the physical aspects of these experiments, however, remained virtually unchanged from that at the other sites.

1.2 OBJECTIVES AND SCOPE OF THE EXPERIMENTS

As with the previous two experiments, the objective of the experiment at Savanna Bay was to determine the location of dredged sand in the river following thalweg disposal. Dredged sand was tagged with dyed sand of similar size and shape during dredging, and surficial bottom sediments were sampled to detect the dyed sand. The presence of dyed sand in the river sediments was used to infer the presence of tagged dredged material. The experience gained at the first two experimental sites led to the establishment of two measurement objectives: sensitive habitat regions away from the disposal site were to be monitored to determine whether dredged sand had reached them, and the disposal site itself was to be surveyed to determine what changes had occurred in the original placement configuration.

The objectives of the experiment at the Duck Creek site were somewhat different from those at the other three sites. The U.S. Fish and Wildlife Service suggested the need to investigate how the disposal piles in the thalweg might influence fish populations. The results at Gordon's Ferry and Whitney Island showed that the dredged sand does not disperse rapidly but remains as a pile in the thalweg until a period of high river discharge. Because dredging is usually carried out in the fall when flows are generally low, the disposal pile may persist through the winter until the normal spring flooding occurs. Thus, the possibility exists that the disposal piles may affect certain fish populations that are thought to winter in the deep areas of the thalweg. The objective of the experiment at the Duck Creek site was to place several disposal piles along the thalweg in a reach of the river where the bottom was normally fairly flat and to carry out fish population studies in the vicinity of these piles. Argonne was to provide the physical data on the locations and sizes of the piles needed to interpret the results of the fisheries studies.

1.3 GENERAL EXPERIMENTAL APPROACH

In consultation with Argonne and the U.S. Fish and Wildlife Service, the Rock Island District considered several factors in selecting the Savanna Bay site. One factor was the need to dredge as part of routine channel maintenance. Another was the suitability of the site for thalweg disposal, that is, the availability of a deep region in the thalweg for disposal within a reasonable distance downstream of the dredging location. A third factor was the interest expressed by the U.S. Fish and Wildlife Service in carrying out fish population studies at a thalweg disposal site in a fairly deep, narrow, fast-flowing reach of the river.

Prior to dredging, Argonne used Corps of Engineers survey data and field markers to establish a coordinate system for the experiment. Bathymetry was measured in the disposal area to determine the existing bottom topography and to locate the deep area where the dredged sand was to be placed. Dyed sand was prepared by the District and delivered to the dredge.

Dredging was accomplished with a hydraulic dredge and booster pump in combination. The dredge proceeded upstream along the dredge cut, pumping sand through a floating pipeline to the booster pump off to the side of the channel. The sand was then pumped to the disposal site in the channel through another floating pipeline. The discharge end of the pipeline could therefore be moved independently of the dredge and actually was moved downstream during the operation in a stepwise fashion by adding sections of pipe to the pipeline. During dredging, Argonne directed and monitored the injection of dyed sand into the suction side of the hydraulic dredge pump.

Shortly after the dredging was completed, Argonne surveyed the disposal and downstream areas. Bathymetry was measured in the disposal area to define the physical size of the disposal pile. Surficial bottom samples were collected at and near the pile and along transects downstream until transects with samples revealing no visible evidence of dyed sand were reached. Subsequent surveys gathered information on changes in the bathymetry of the pile and the distribution of dyed sand in the surficial sediments.

The Duck Creek site was selected because the thalweg is very wide and flat in that reach and because the site is fairly close to the Savanna Bay site. Prior to dredging, Argonne conducted a bathymetric survey at the site to serve as a reference for subsequent identification of the disposal piles. Dredging was not required for channel maintenance at this site but was carried out expressly to create disposal piles in the thalweg for the fish population studies. A bathymetric survey was conducted immediately following the dredging operation to determine the location and size of the disposal piles. Subsequent bathymetric surveys were conducted over a nine-month period to monitor changes in the size and shape of the piles.

1.4 EXPERIMENTAL SITES

Figure 1 is a generalized map of the Upper Mississippi River. The locations of the Savanna Bay and Duck Creek experimental sites are shown, along with the locations of the two original experimental sites.

1.4.1 Savanna Bay Site

The Savanna Bay experimental site is in Pool 13 about 26 km (16 mi) upstream of Lock and Dam 13 at Clinton, Iowa, and about 3.2 km (2 mi) upstream of Savanna, Illinois. As indicated in Fig. 2, the area dredged in October 1983 is located at about river mile 539.2 (measured from the confluence with the Ohio River), and the disposal area is near river mile 538.7. Both areas are just upstream of the downstream entrance to Savanna Bay.

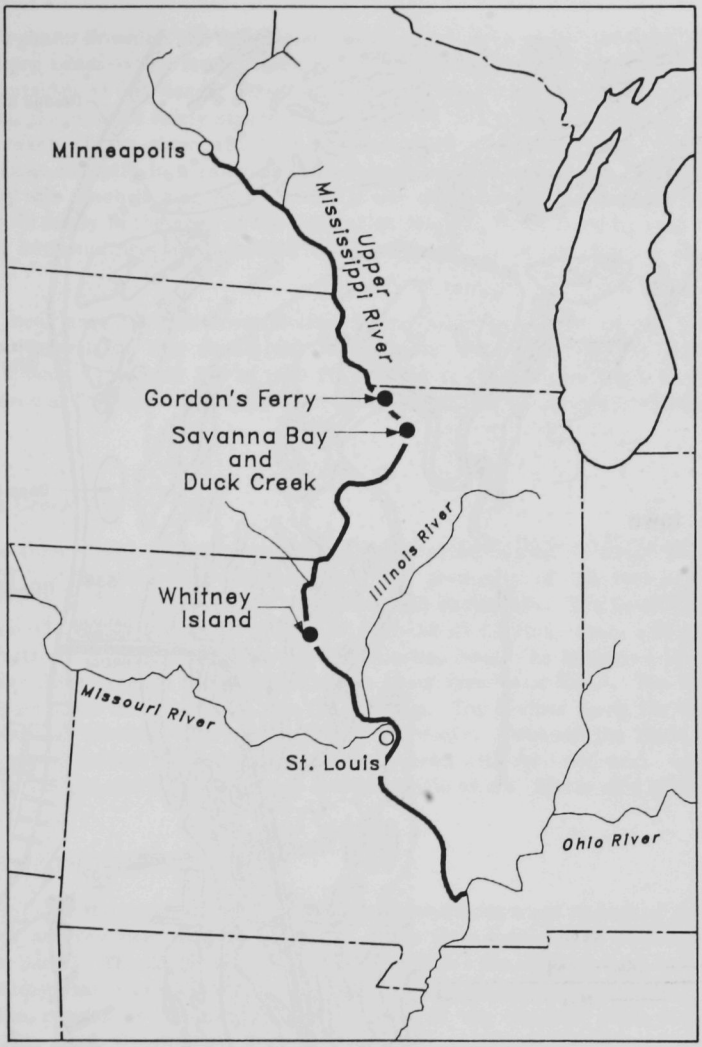

FIGURE 1 Location of Experimental Sites along the Upper Mississippi River

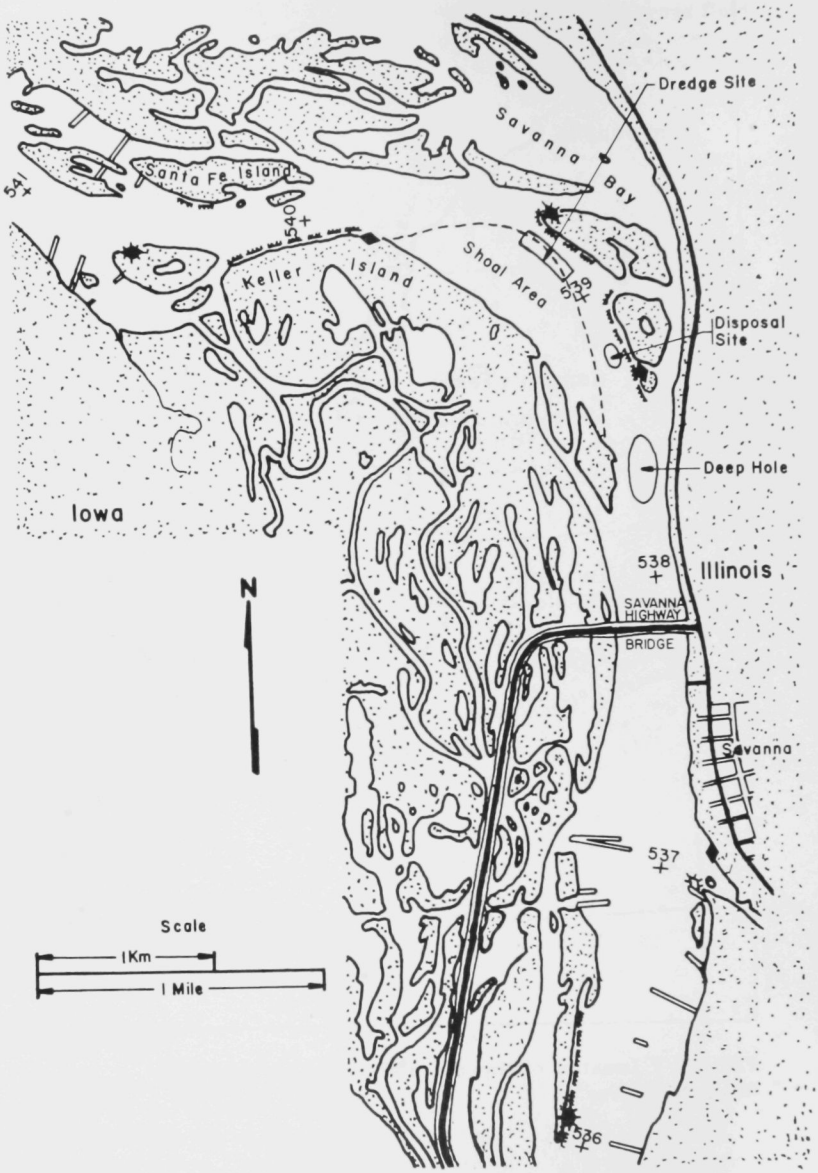

FIGURE 2 Savanna Bay Experimental Site in Pool 13 of the Upper Mississippi River

The reach in which the experiment was conducted is at the downstream end of a series of sharp bends in the river. Rock revetments protect various sections of the shore along the outsides of the bends. Starting at the disposal site and for about 3 km (2 mi) downstream, the river is fairly straight. A deep hole (>12 m [>40 ft] deep) occurs in the restricted reach of the river centered at about river mile 538.3. The Illinois bank is steep and rises abruptly in a railroad embankment reveted with rock. The Iowa side of the river in this reach is marked by lowlands cut through with sloughs and backwaters. The bottom is sandy in the area of the navigation channel, but it is rocky near the Illinois shore. Silt and mud are found toward the Iowa side. Dunes are common in the sandy areas.

A shoal area extends from Kellers Island along the inside of the bend in the river. The growth of this shoal into the channel had restricted the width of the navigation channel to about 120 m (400 ft), making it difficult for large barge tows to maneuver around the bend. Dredging was required to widen the navigation channel at the bend.

1.4.2 Duck Creek Site

The Duck Creek experimental site is also located in Pool 13 about 24 km (15 mi) upstream of the Savanna Bay disposal site. The proximity of the two sites made it possible to monitor both sites during the same field excursions. The Duck Creek site is about 50 km (31 mi) upstream of Lock and Dam 13 at Clinton, Iowa, and about 5 km (3 mi) downstream of Lock and Dam 12 at Bellevue, Iowa. As indicated in Fig. 3, the disposal piles were created in October 1983 at about river mile 553.6. The thalweg lies along the Iowa shore and is about 8.5 m (28 ft) deep. The bottom along the thalweg and the Iowa shore is covered with coarse gravel and rocks. Between the thalweg and the Illinois shore, the bottom rises gradually and is covered with sand and mud. Lowlands cut through with sloughs and backwaters are characteristic of the Illinois side of the river.

1.5 SCOPE OF THIS REPORT

Details of the experimental procedures and methods were presented in a previous volume[1] but are reviewed briefly in Sec. 2. The field experiment at Savanna Bay is described in Sec. 3. The dredging and disposal operations are discussed, as are the results of five postdisposal surveys over a nine-month period following dredging. Section 4 discusses the results of the bathymetric surveys of the disposal piles placed in the thalweg at the Duck Creek site. Section 5 summarizes the results from these two field experiments and compares the results with those from the experiments at Gordon's Ferry and Whitney Island.[1]

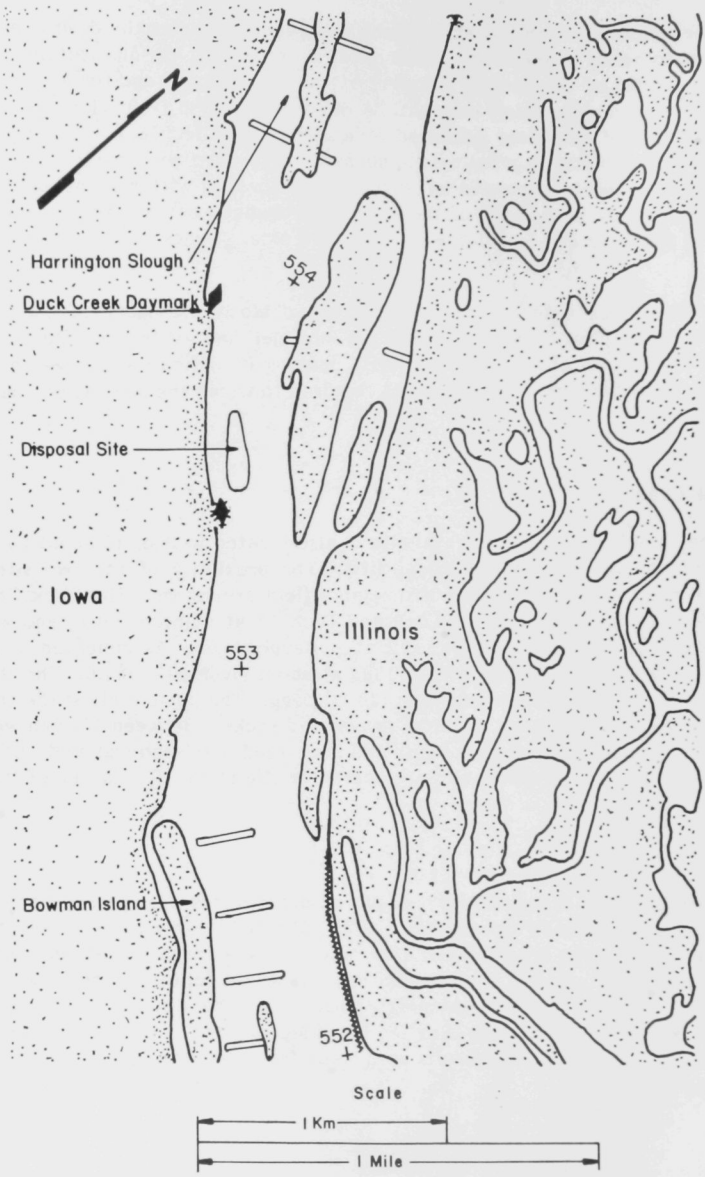

FIGURE 3 Duck Creek Experimental Site in Pool 13 of the Upper Mississippi River

2 EXPERIMENTAL PROCEDURES

Section 2 briefly summarizes the experimental procedures that are discussed in detail in ANL/EES-TM-169[6] and ANL/EES-TM-270, Vol. 1.[1]

2.1 DREDGING AND TAGGING OPERATION

Sand dying and dredging were carried out in the same manner as at the previous two experimental sites, Gordon's Ferry and Whitney Island. The sand to be dyed was selected to match as closely as practical the grain-size distribution of the natural sand at the dredge site. It was dyed by the Corps of Engineers with Day-Glo Rocket Red (AX13)™, packed in bags containing about 31 kg (70 lb) each, and loaded onto a barge for transportation to the experimental site.

The same dredge was used as for the other two sites -- the Corps of Engineers' dredge *William A. Thompson*. At Savanna Bay, as at Whitney Island, a booster pump was required because of the large distance between the dredge and the point of discharge. Dyed sand was injected in the same manner as in the previous two experiments but with an injection rate of about 7.3 kg/min (16 lb/min), resulting in an estimated concentration of dyed sand by weight of about 480 ppm in the dredged sand. The spreading device that was attached to the end of the discharge pipe at the first two experimental sites was not used at either Savanna Bay or Duck Creek. Instead, the effluent was discharged directly from the open end of the horizontal pipeline about 1 m (3 ft) above the surface of the water.

2.2 SURVEY PROCEDURES

The disposal area and downstream areas were surveyed to determine the location of the tagged disposal material and changes in river bottom bathymetry. A 7.6-m (25-ft) Monark aluminum work boat was used for all surveys. A Motorola Mini-Ranger™ system interfaced with a Hewlett-Packard programmable calculator and an x-y flatbed plotter was used for real-time boat positioning. Typically, the position of the boat could be determined to within a few meters. A rectangular coordinate system was established at each experimental site. Shorelines and other features were digitized in terms of this coordinate system using charts supplied by the District. Plotter charts that included sampling locations, shorelines, and other features of interest were prepared for the onboard x-y plotter in advance of each survey.

Bathymetry was measured with a Raytheon recording depth sounder by driving the boat along preestablished straight-line transects at a constant speed. Marks were placed on the depth-sounder record corresponding to transect end points on the x-y plotter charts. The depth-sounder record was then interpolated between those end points. The boat usually stayed within 5-10 m (15-30 ft) of the established transect, but deviations of as much as 20 m (65 ft) did occasionally occur due to changing currents or winds.

For each survey, surficial bottom samples were initially collected at predetermined stations based on the original disposal location or previous survey results. The spacing between stations varied with proximity to areas of high concentration of dyed sand. In the immediate disposal area, where concentrations of dyed sand were high, sample spacing was about 25 m (80 ft) laterally and 50 m (160 ft) longitudinally. Downstream and to the sides of the disposal area, where concentrations of dyed sand were smaller, sample spacing was increased to 50-100 m (160-330 ft) laterally and 100-400 m (330-1310 ft) longitudinally.

The boat was driven to the sampling location, and a surficial bottom sample was collected with a Ponar Grab Sampler™. A portion of the sample was spread onto a 23 × 23 cm (9.1 x 9.1 in.) tray for visual inspection and photographing while illuminated by ultraviolet light. (Exposure times were 2, 7, and 12 s for each sample.) Finally, the classification of the bottom material by grain size was visually estimated.

Estimating the amount of dyed sand in each bottom sample as it was collected permitted subsequent sampling locations to be adjusted to better delineate the extent of the tagged sand. (It should be noted, however, that small dyed sand grains that were later visible in the photographs were not always visible during the onboard examination.) Finally, each sample was placed in a labeled polyethylene container and saved in case additional analysis might be required.

2.3 DATA REDUCTION

After each field survey, positioning-system plotter charts, depth-sounder strip charts, exposed photographic film, bottom samples, and other data records were returned to Argonne for processing. Data were extracted from these records and stored in a format convenient for tabular and graphic presentation by the Argonne computer.

2.3.1 Bathymetric Data

Water depth information from the depth-sounder strip chart was digitized, and the data were stored in the Argonne computer. By interpolating the digitized data between the transect end points and correcting for water level changes, bottom profiles could be plotted by the computer. Even though the attempt was made to follow the same bathymetric transects on subsequent surveys, the boat did deviate in varying degree from the prescribed paths. Therefore, only general trends in changes of topographic features should be considered significant. Detailed comparisons between individual transects on subsequent surveys are not recommended.

2.3.2 Bottom Samples

The bottom samples were stored in case further analysis might be required, particularly with regard to the photographic records. The photographic film was developed and processed into slides, which were labeled and stored in standard Kodak Carousel™ slide trays. Each series of slides (various exposure times) corresponding to individual bottom samples was examined, and the number of dyed sand grains visible on

the surface of the sample tray was determined by direct count or, if the number was very large (>200), by estimation. The coordinates of the sampling locations were extracted from the positioning-system plotter charts, and all information was stored in the Argonne computer. The data record for each sample includes:

- Collection date,
- Collection time,
- Sample identification number,
- Sampling location (x-y coordinates),
- Approximate water depth at sampling location,
- Number of dyed sand grains visible in the photographic slides of the sample tray,
- Classification of the sample by approximate grain size, and
- Identification number for the photographic slides.

Computer programs were used to present several of these parameters in various graphical formats.

3 FIELD EXPERIMENTS AND RESULTS AT SAVANNA BAY

Section 3 describes the field measurements and presents the data from the experiment at Savanna Bay. Section 3.1 reviews the tagging and disposal operations, and Sec. 3.2 discusses the first survey (Survey I) and describes the conditions of the disposal pile immediately following the dredging operation. Section 3.3 discusses the subsequent surveys (Surveys II-V), while Sec. 3.4 briefly summarizes the experimental results. The important experimental activities conducted at Savanna Bay are summarized in Table 1. Figure 4 is a plot of mean daily river discharge recorded by the Rock Island District at Lock and Dam 13, about 26 km* downstream of the disposal area.

TABLE 1 Experimental Activities at the Savanna Bay Site

Experimental Activity	Date	Time after Disposal (days)[a]	Number of Bottom Samples Collected
Background bottom samples	October 5, 1983	-21	10
Predisposal bathymetry	October 24, 1983	-2	NA[b]
Dredging and disposal operations	October 25-26, 1983	0	NA
Survey I	October 27-29, 1983	1	151
Survey II	November 7-9, 1983	12	132
Survey III	December 13-14, 1983	48	49
Survey IV	March 27-29, 1984	153	74
Survey V			
Bathymetry	August 1, 1984	280	NA
Bottom samples	August 8-9, 1984	287	135

[a]Time from the end of disposal operations on October 26, 1983.

[b]Not applicable.

*In Sec. 3 and the following sections of this report, conversions to English units will not be provided.

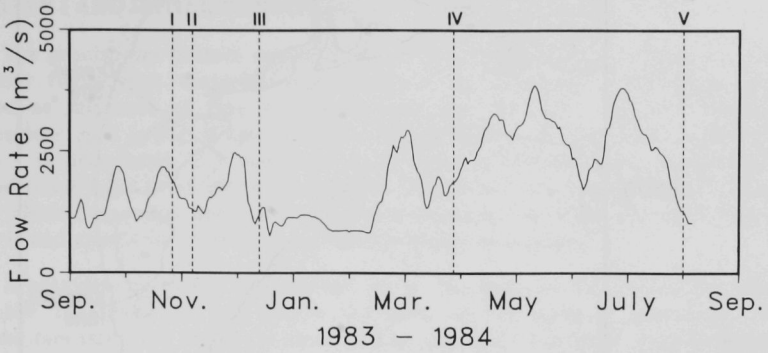

FIGURE 4 Mean Daily River Discharge for the Savanna Bay Site as Recorded at Lock and Dam 13, with the Dates of the Surveys Indicated

3.1 DREDGING, TAGGING, AND DISPOSAL OPERATION

Dredging at Savanna Bay by the *Thompson* began on October 25, 1983, at 1007 hr at the downstream end of the cut area indicated in Fig. 5. Dyed sand was injected into the dredge line as described in ANL/EES-TM-270, Vol. 1.[1]

The sand-disposal operation at Savanna Bay was similar to the operation at Whitney Island, in that the dredging and disposal sites were separated by as much as 1 km and an auxiliary pump barge was required to transport the dredged sand to the disposal site. The pump barge remained anchored off to the side of the channel. Therefore, the discharge end of the pipeline was not directly connected to the *Thompson* and moved independently of the upstream progress of the dredge. At Savanna Bay the end of the discharge pipeline was moved downstream in a stepwise manner by inserting individual sections of pipe into the pipeline.

River flow was unusually high for the fall season, so that anchoring the discharge end of the pipeline against the current was difficult and lateral movement could not be achieved as readily as at the previous two experimental sites. Some lateral movement of the end of the discharge pipe could be effected by changing the tension on the anchor lines that secured it, but the maximum excursion was only about 25 m. As a result, several overlapping mounds of dredged sand were formed along the disposal area. This configuration was similar to that formed during the experiment at Whitney Island but was in contrast to the single elongated pile formed at Gordon's Ferry. The water depth under the end of the discharge pipe was monitored closely during the dredging operation because the mounds built up very quickly when the dredge cut was heavy.

The sand that was dyed for the tagging procedure was from an old river deposit about 1.5 km from the present river near Muscatine, Iowa. A sieve analysis of the sand, prior to dyeing, indicated that the median grain size, d_{50}, was about 0.75 mm; the

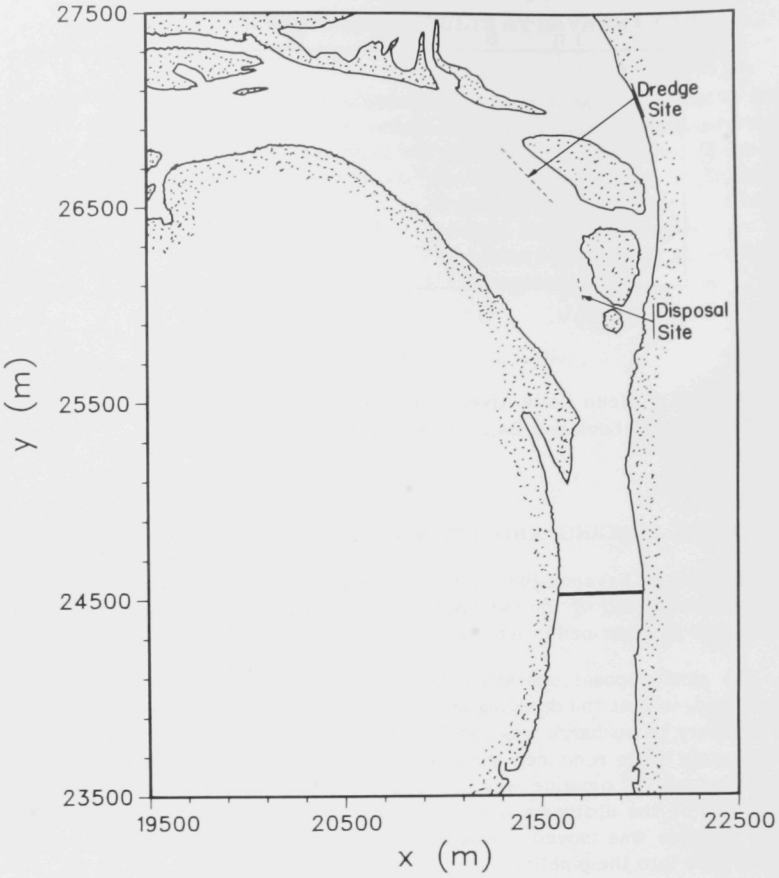

FIGURE 5 Map of Savanna Bay Site Showing Dredging and Disposal Areas

geometric mean grain size, d_g, was about 0.85 mm; and the geometric standard deviation, σ_g, was about 2.1. In general, the sand could be classified as medium grained. The sand was dyed by the Rock Island District in the manner described in ANL/EES-TM-270, Vol. 1.[1]

The average initial concentration, by weight, of dyed sand was about 480 ppm. This estimate is based on the expected volume of the dredge cut (about 11,600 m^3), the total amount of dyed sand injected (about 8900 kg), and a mass to volume ratio for sand of 1600 kg/m^3. Thus, the initial dyed sand concentration for the Savanna Bay experiment (480 ppm) was about half as great as that in the Gordon's Ferry experiment (1000 ppm) and about five times greater than at Whitney Island (90 ppm). In contrast to the other two experiments, all of the sand dredged at Savanna Bay was tagged with dyed sand.

3.2 SURVEY I AND INITIAL CONDITIONS

The predisposal bottom sampling survey was conducted on October 5, 1983. No interfering fluorescent material was noted in the samples, which were generally classified as mixtures of fine to coarse sand (see Fig. 6). The key for sediment classifications used in Fig. 6 and all other similar figures is: Y - mud, S - silt, F - fine sand, M - medium sand, C - coarse sand, G - gravel, and R - rock. Sediments were classified based on a brief visual inspection. Therefore, exact correlation between the onboard visual inspection and a sieve analysis should not be expected. However, gross changes in sediment character between surveys should be apparent.

A bathymetric survey was carried out at the Savanna Bay site on the afternoon of October 24, 1983, the day before the start of the dredging operation. Twelve transverse (across-river) transects about 300 m long and 50 m apart were established in the disposal area. Figure 7 shows the results from some of these transects in the form of a perspective plot, with the base of the plot taken arbitrarily at a depth of 15 m. The direction of flow of the river is from the top to the bottom of the plot. The river bottom is fairly flat and only a few meters deep along the western shore. A 10-m-deep channel runs along the eastern side of the river just west of the islands that divide the river proper from the mouth of Savanna Bay. The rock revetments, which protect these islands from flow in the main channel, often prevented bathymetric measurements from being made close to the eastern edge of the channel.

In addition to the transverse transects, four longitudinal (along-river) transects 50 m apart were established in the same area. The results from these transects, as well as from the 12 transverse transects, are presented in Sec. A.1 of App. A. The longitudinal transects exhibited a wavelike dune structure in the area of the channel, with a wavelength of about 30 m and a trough-to-crest amplitude of 1-1.5 m.

The dredging and disposal operation was completed in the early evening of October 26, 1983. Another bathymetric survey (Survey I) was made the following morning, which covered the same general area as the previous survey, but which included 18 transverse transects with a spacing of about 25 m instead of 50 m. The closer spacing was designed for accurate delineation of the disposal pile. The results of this first postdisposal bathymetric survey are shown in Fig. 8 and are included in Sec. A.1 of App. A.

Evidence of the pile formed by the disposal operation can be seen in the fifth through the 12th transects (counting from the upstream end) along the western edge of the deep channel, where the water depth was originally about 8.5 m deep. In general, the peak of the pile was located between x = 21,700 m and x = 21,750 m. The pile extended downstream from about y = 26,110 m to about y = 25,950 m, for a total length of about 170 m. The pile was not uniform over its length and appeared to consist of a series of overlapping mounds of various heights and widths. The height of the disposal pile above the local natural bottom ranged from 0.7 m to 3.1 m, with an average height of 1.9 m. The width at the base of the pile ranged from 25 m to 55 m, with an average width of about 45 m.

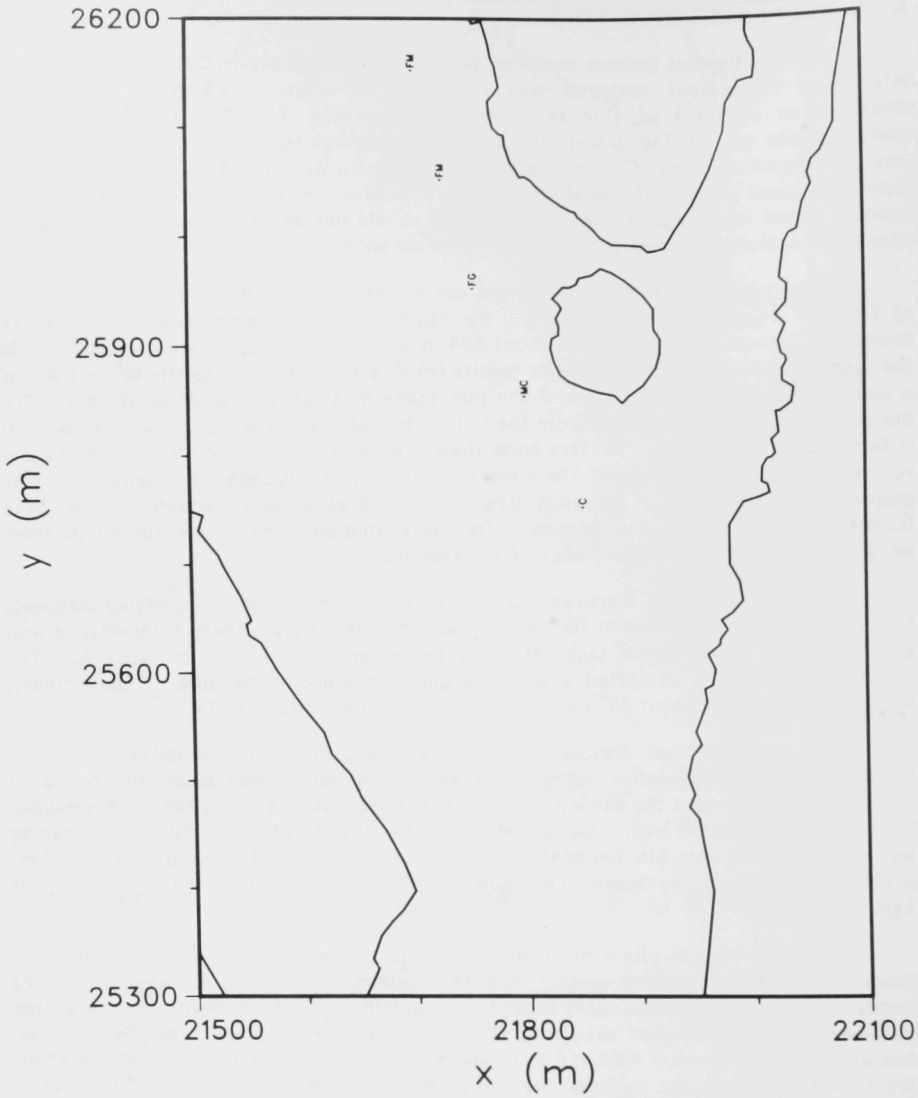

FIGURE 6 Approximate Classification of Bottom Sediments at Sampling Locations during the Predisposal Survey at the Savanna Bay Disposal Site

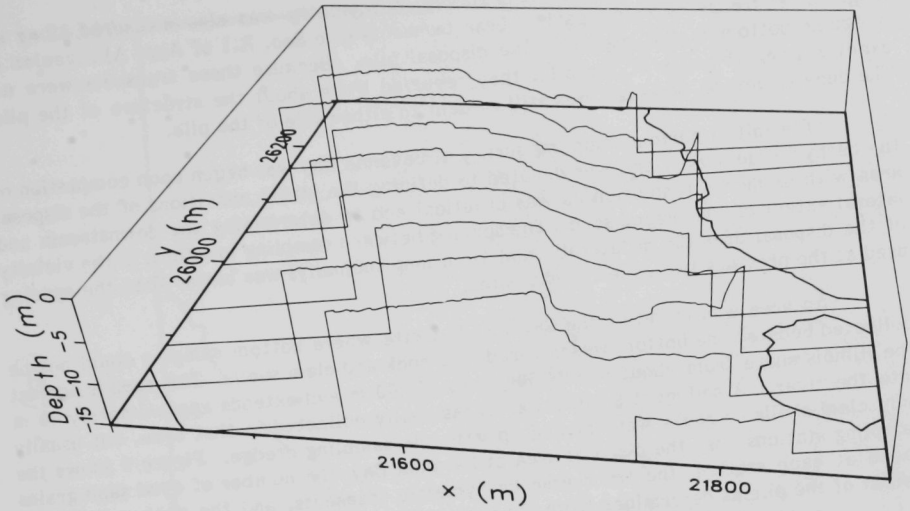

FIGURE 7 Perspective Plot of Transverse Bathymetric Transects for the Predisposal Survey at the Savanna Bay Disposal Site

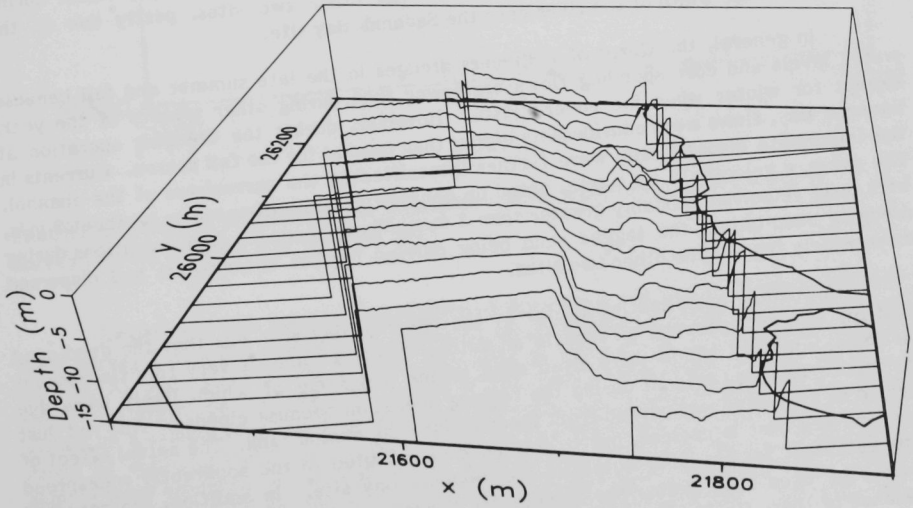

FIGURE 8 Perspective Plot of Transverse Bathymetric Transects for Survey I at the Savanna Bay Disposal Site

During this first postdisposal survey, bathymetry was also measured along six longitudinal transects 25 m apart. These transects (see Sec. A.1 of App. A) revealed an irregular bottom in the region of the disposal pile. Because these transects were not exactly along the axis of the pile, they revealed little about the structure of the pile. The dune structure, however, was still evident to either side of the pile.

The initial bottom sampling survey at Savanna Bay was begun upon completion of the bathymetric survey and was devoted to defining the initial conditions of the disposal area with as high a resolution as was practical and to determining the downstream and lateral extent of the tagged sand. The spacing between sampling locations in the vicinity of the disposal area (25 m laterally and 50 m longitudinally) was closer than the spacing used at the previous two experimental sites.

An area was found at the Savanna Bay site where bottom samples could not be collected because the bottom was covered with rock and clam shells. This area is against the Illinois shore from about y = 24,500 m to 25,500 m and extends approximately 40 m into the river. A sediment sample was occasionally collected in that area, but usually only clam shells or rocks were picked up with the sampling dredge. Figure 9 shows the sampling stations near the disposal area at Savanna Bay, the number of dyed sand grains found at each station, the transverse bathymetric transects, and the peak and lateral extent of the pile as determined from the bathymetric survey results.

The tagged sand at the Savanna Bay site was initially more widely distributed, both downstream and laterally, than at either of the previous two experimental sites. This pattern can probably be attributed to the current being considerably faster during the dredging operation than the current at the other two sites, partly due to the restriction in the width of the river near the Savanna Bay site.

In general, the Corps of Engineers dredges in the late summer and fall because water levels and corresponding flows are lower than during other seasons of the year, except for winter when ice cover exists. However, during the dredging operation at Savanna Bay, flows were considerably higher than normal for the fall season. Currents in the immediate disposal area were further intensified by the narrowness of the channel. The average velocity in that area, based on continuity, was estimated to be about 2 m/s, with peak velocities probably greater than 3 m/s. These abnormal flow conditions during dredging resulted in the tagged sand being carried farther downstream and dispersed more widely than at the other two sites.

A further complicating factor at the Savanna Bay site was that the dyed sand used for tagging appeared to contain an extraordinary amount of very fine fluorescent particles, some of which were dyed sand grains and some of which likely were dye particles. This was evident during the tagging operation because clouds of fine red dust formed as dyed sand was poured from the bags into the mixing tank. The actual effect of this fine red dust is unclear, but it may have contributed to the apparently widespread distribution of tagged sand noted at the Savanna Bay site. In addition, the reported number of dyed sand grains per sample for Survey I may be inflated because of the presence of these fine particles.

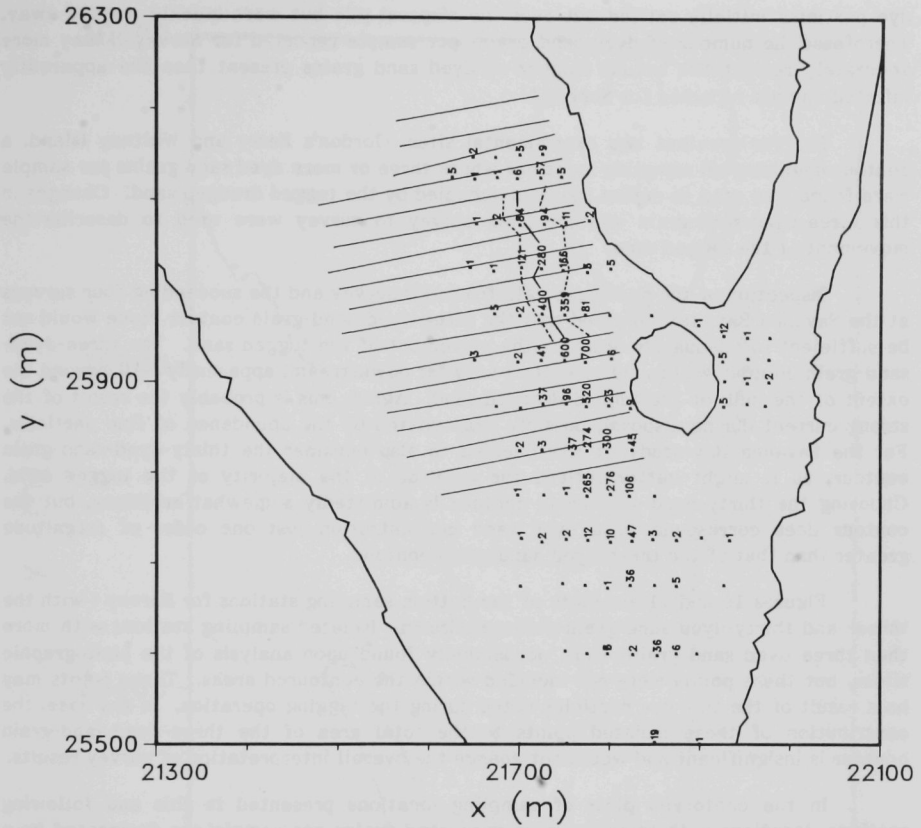

FIGURE 9 Location of Bathymetric Transects and Bottom Sampling Stations for Survey I at the Savanna Bay Disposal Site

Evidence of this inflation is provided by comparing the counts of dyed sand grains from Survey I with the counts from Survey II, ten days later (see Sec. 3.3.1 and Sec. A.2 of App. A), and by comparing Survey I data with an estimate of the expected number of dyed sand grains per sample. Estimates of the maximum number of dyed sand grains visible on a sample tray based on an initial concentration by weight of 480 ppm are in the range of approximately 100 to 200. However, as many as 700 dyed sand grains per sample were observed on the first survey, with several stations in the immediate disposal area yielding more than 400 -- several times larger than predicted. The maximum number of dyed sand grains per sample on the second survey was 215 -- very close to the predicted number.

The change between the first two surveys was also much larger than noted at the previous two sites. While other explanations are possible, it may be that the very fine

dye particles initially settled out over the disposal pile but were quickly washed away. Therefore, the number of dyed sand grains per sample reported for Survey II may more accurately reflect the actual number of dyed sand grains present than the apparently inflated number reported for Survey I.

For the previous two experimental sites, Gordon's Ferry and Whitney Island, a contour enclosing all sampling locations where three or more dyed sand grains per sample were found was used to define the area occupied by the tagged dredged sand. Changes in this three-dyed-sand-grain contour from survey to survey were used to describe the movement of the tagged sand.

Inspection of the dyed sand data from this survey and the succeeding four surveys at the Savanna Bay site indicated that the three-dyed-sand-grain contour alone would not be sufficient to adequately describe the movement of the tagged sand. The three-dyed-sand-grain contour was found to extend very far downstream, apparently well beyond the extent of the bulk of the tagged dredged sand. Again, this is probably the result of the strong current during disposal, possibly exacerbated by the abundance of fine particles. For the Savanna Bay study, it was decided to also consider the thirty-dyed-sand-grain contour, as it might better reflect the location of the majority of the tagged sand. Choosing the thirty-dyed-sand-grain contour is admittedly somewhat arbitrary, but the contour does correspond to a dyed sand concentration just one order of magnitude greater than that of the three-dyed-sand-grain contour.

Figures 10 and 11 are plots of the bottom sampling stations for Survey I with the three- and thirty-dyed-sand-grain contours drawn. Isolated sampling stations with more than three dyed sand grains were occasionally found upon analysis of the photographic slides, but these points were not included within the contoured areas. These points may be a result of the tiny dye particles noted during the tagging operation. In any case, the contribution of these isolated points to the total area of the three-dyed-sand-grain contour is insignificant and would not change the overall interpretation of survey results.

In the contoured plots of sampling locations presented in this and following sections, locations with three or more dyed sand grains per sample are designated by a filled symbol, and sampling locations with less than three dyed sand grains per sample are designated by an open symbol. In Figs. 10 and 11, the three-dyed-sand-grain contour extends from about y = 24,100 m to 26,200 m, a longitudinal distance of 2.1 km. The area enclosed by the contour is about 170,000 m^2. The three-dyed-sand-grain contour extends about 1.8 km downstream of the bathymetrically distinguishable pile, a much greater distance than at the other two sites (500 m at Gordon's Ferry and 200 m at Whitney Island). This greater downstream extent is probably due to the strong current flowing during the disposal operation.

The lateral position within the river of the three-dyed-sand-grain contour tended to follow the classical pattern of a thalweg through a bend and crossing sequence. That is, after sweeping around the outer radius (Illinois side of the river) of the sharp bend in the disposal area, the contour tended to cross back over the river toward the Iowa side. Some bathymetric measurements were taken in the downstream area but not with the same resolution used in the disposal area. These measurements indicated that the actual position of the thalweg south of about y = 25,000 m is less well defined as the river

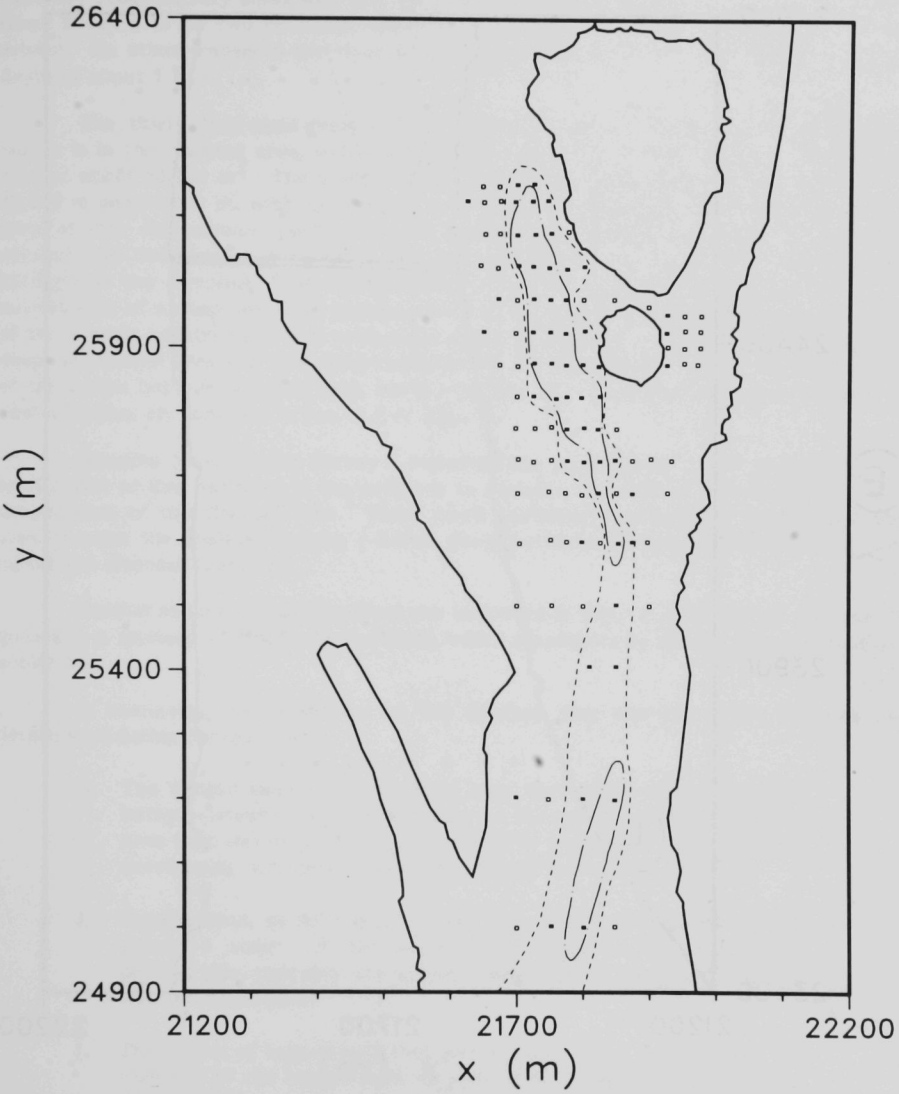

FIGURE 10 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours for Survey I at the Savanna Bay Disposal Site

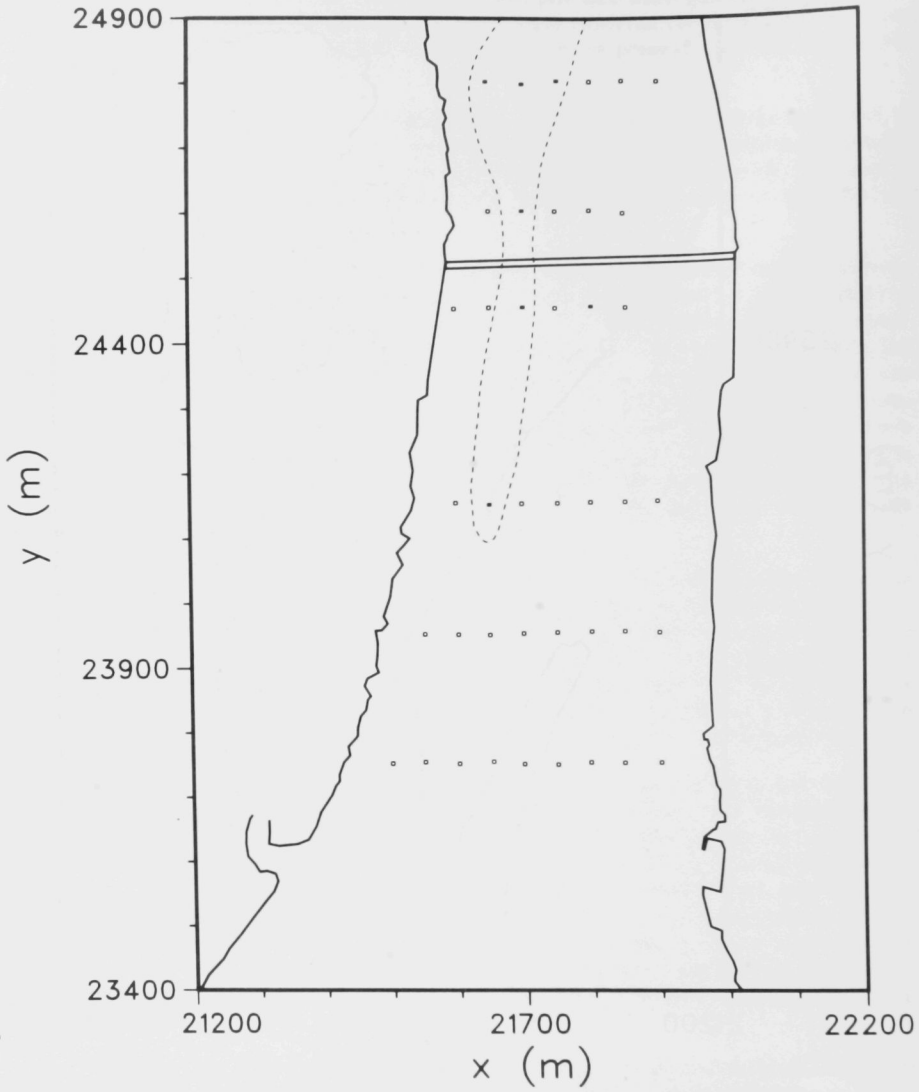

FIGURE 11 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours (if present) for Survey I Downstream of the Savanna Bay Disposal Site

becomes progressively shallower and the bottom becomes flatter. On some transects there appears to be two channels, one near each shore, with a shallower region in the center. On other transects the river bottom appears to be nearly flat, with an average depth of about 7 m.

The thirty-dyed-sand-grain contour encloses two separate regions. The larger region is in the disposal area, extending downstream to y = 25,600 m, with an enclosed area of about 20,000 m^2. The second region is much smaller, being located between y = 25,000 m and 25,200 m, with an enclosed area of about 10,400 m^2. (This estimate of the area of the downstream portion of the thirty-dyed-sand-grain contour is not very accurate, as the contour is based on only two sampling stations with more than 30 dyed sand grains per sample.) This second region of higher dyed sand concentration is just downstream of a deep hole (>12 m deep, see Fig. 2) occurring in an area where the width of the river is constricted. It is probably a result of tagged sand being swept through the deep constricted area and then being deposited on the downstream side of the hole. Plots of the entire bottom-sampling grid, along with the number of dyed sand grains found at each location, are included in Sec. A.2 of App. A.

Samples taken during Survey I indicated the presence of a few very fine dyed sand grains or dye particles in the entrance to Savanna Bay east of the small island just downstream of the disposal area. These small particles were possibly washed into the area through the shallow opening (~1.5 m deep) between the two islands (see Fig. 10) during the disposal operation.

Bottom sediment classifications are indicated in Fig. 12. The bottom material is generally a mixture of fine to coarse sand, which represents no change from predisposal conditions.

In summary, the conditions at the Savanna Bay site just after dredging, as determined during Survey I, were:

1. The tagged sand in the disposal area that could be distinguished bathymetrically from other bedforms (termed the pile) covered an area that was about 170 m long and 45 m wide. The pile comprised overlapping mounds that ranged in height from 0.7 m to 3.1 m.

2. Tagged sand, as delineated by the three-dyed-sand-grain contour, extended about 1.8 km downstream from the bathymetrically defined pile, probably due to the strong current present during the disposal operation.

3. The region of tagged sand that was probably more indicative of the majority of the tagged sand, as delineated by the thirty-dyed-sand-grain contour, was divided into two portions: the upstream portion in the immediate disposal area, which was about 600 m long and 60 m wide, and the downstream portion, which was on the downstream side of a deep hole and which was about 300 m long and 30 m wide.

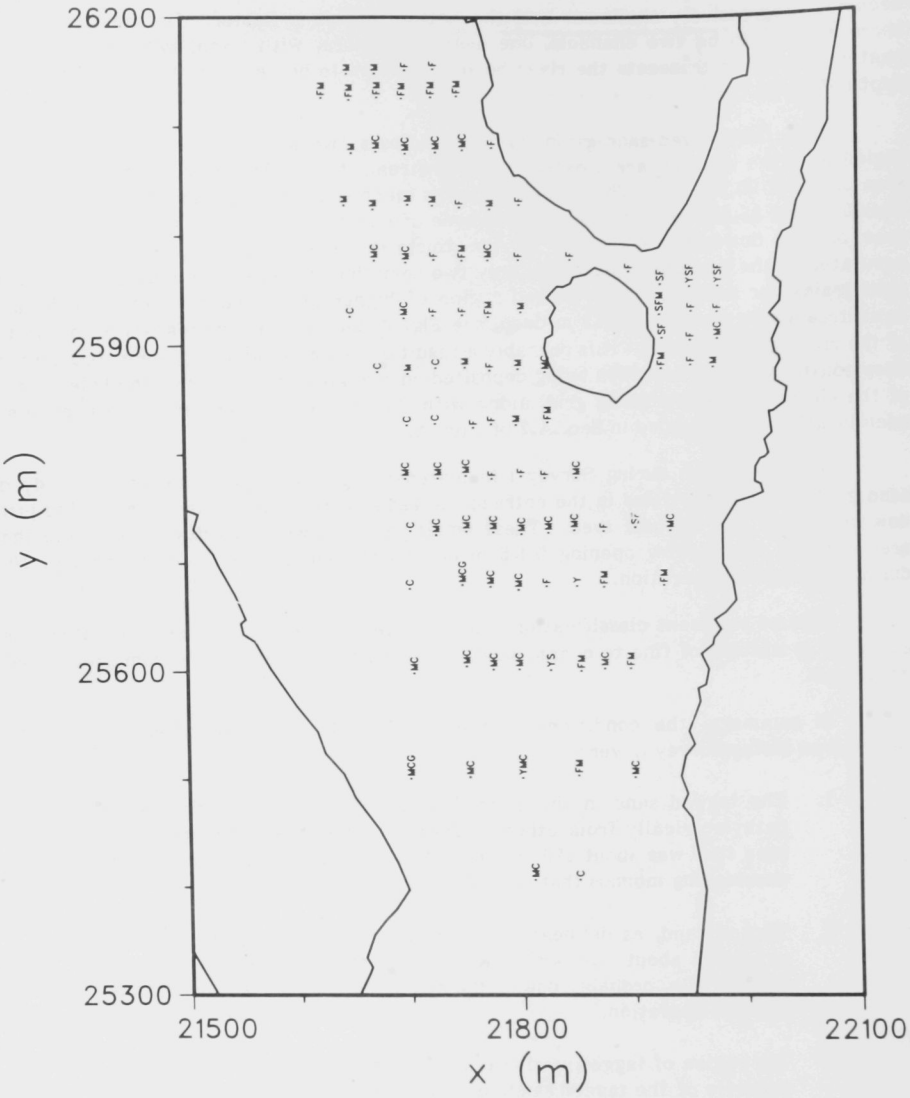

FIGURE 12 Approximate Classification of Bottom Sediments at Sampling Locations for Survey I at the Savanna Bay Disposal Site

4. The surficial bottom sediments were generally a mixture of fine to coarse sands, with no grain size apparently predominating and no significant change from predisposal conditions.

3.3 RESULTS OF SUBSEQUENT SURVEYS

3.3.1 Survey II

On November 7, 1983, 10 days after the first postdisposal survey, a second bathymetric survey was made, which followed the same 18 transverse and six longitudinal transects as closely as possible. Because it was difficult to maintain a specific boat course in the presence of river currents and winds, the transects did not coincide exactly with those of Survey I, although they were typically within 5-10 m of each other. Detailed comparisons between corresponding transects are not appropriate; only general trends in changes in bottom topography should be considered meaningful. Five transverse transects were added downstream of the original 18, and one longitudinal transect was added west of the original six. The results from most of the transverse transects are shown in Fig. 13, with the detailed results from all the transects included in Sec. A.1 of App. A. The disposal pile was still an obvious feature with little change evident since Survey I.

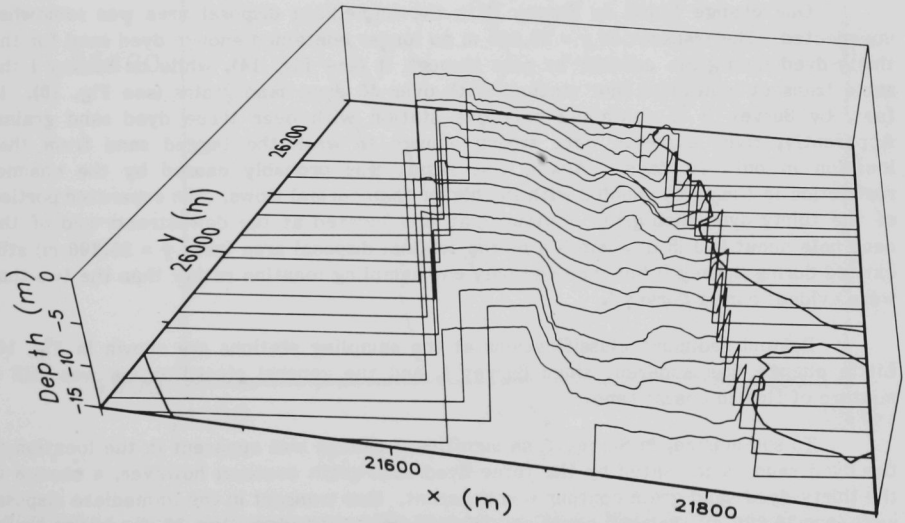

FIGURE 13 Perspective Plot of Transverse Bathymetric Transects for Survey II at the Savanna Bay Disposal Site

The bottom sampling locations for Survey II, with the three- and thirty-dyed-sand-grain contours drawn, are shown in Figs. 14 and 15. Detailed station-by-station results are given in Sec. A.2 of App. A. Little change had occurred in the location of the three-dyed-sand-grain contour since Survey I, and the total area enclosed was about 143,000 m^2. In the region between about y = 25,200 m and y = 24,400 m, it appeared that the contour was wider and that it was discontinuous near the transect at y = 24,600 m. However, these apparent changes are based on changes in the number of dyed sand grains at only a few sampling locations and may be an artifact of the sampling pattern.

There is some indication of downstream migration of tagged sand near the downstream end of the three-dyed-sand-grain contour and beyond. Two additional stations on the transect at y = 24,200 m were found with three or more dyed sand grains, and several stations on the transect at y = 23,750 m contained more dyed sand grains in Survey II than in Survey I. Some of these changes may be attributable to the movement of the very fine dye particles as discussed in Sec. 3.2.

The number of dyed sand grains per sample in the disposal area and in the vicinity of the thirty-dyed-sand-grain contours exhibited significant changes. The number of dyed sand grains per sample in the disposal area was reduced, on average, by about a factor of three. This decrease is probably attributable to the fine dye particles being washed away. The maximum number of dyed sand grains per sample in the disposal area found during Survey II is about what had been expected based on the ratio of dyed sand to dredged sand introduced during the tagging operation.

One change found on Survey II in the immediate disposal area was somewhat unexpected. The transect at y = 25,825 m no longer contained enough dyed sand for the thirty-dyed-sand-grain contour to pass through it (see Fig. 14), while on Survey I the same transect contained four stations with over 30 dyed sand grains (see Fig. 10). In fact, by Survey II it contained only one station with over three dyed sand grains. Apparently, river currents were strong enough to wash the tagged sand from that location in only 10 days. Again, this result was probably caused by the channel restriction in the area, coupled with the higher than normal flows. The separated portion of the thirty-dyed-sand-grain contour that was located at the downstream end of the deep hole about 800 m downstream of the original disposal area (near y = 25,200 m) still existed during Survey II but included only one sampling location rather than the two that were evident during Survey I.

Bottom sediment classifications at the sampling stations are shown in Fig. 16. Little change was apparent since Survey I, and the general classification was still a mixture of fine to coarse sand.

To summarize, in Survey II no significant change was apparent in the location of the dyed sand as indicated by the three-dyed-sand-grain contour; however, a change in the thirty-dyed-sand-grain contour was apparent. One transect in the immediate disposal area (y = 25,825 m) that had contained four stations with more than 30 dyed sand grains per sample on Survey I was found on Survey II to contain no stations with 30 or more dyed sand grains. In fact, it contained only one station with more than three dyed sand grains. No change was noted in the classification of the bottom sediments, and no significant change in bathymetry was apparent.

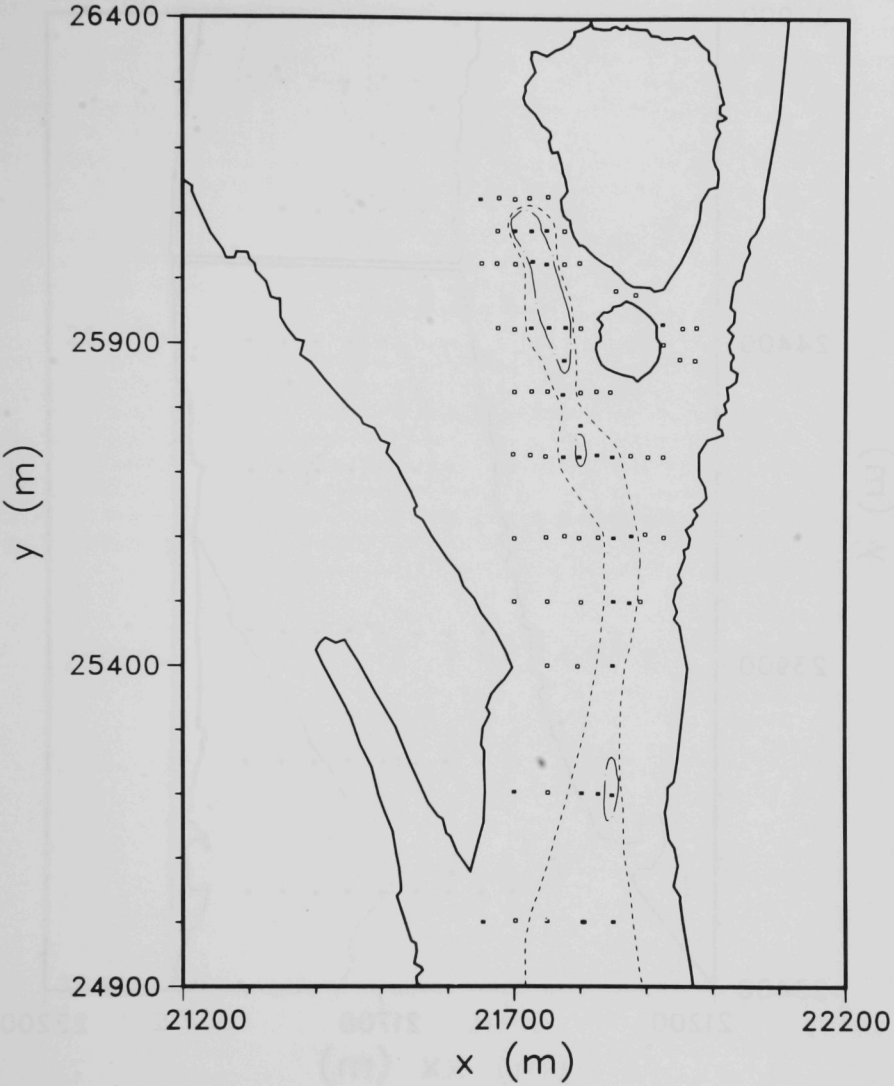

FIGURE 14 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours for Survey II at the Savanna Bay Disposal Site

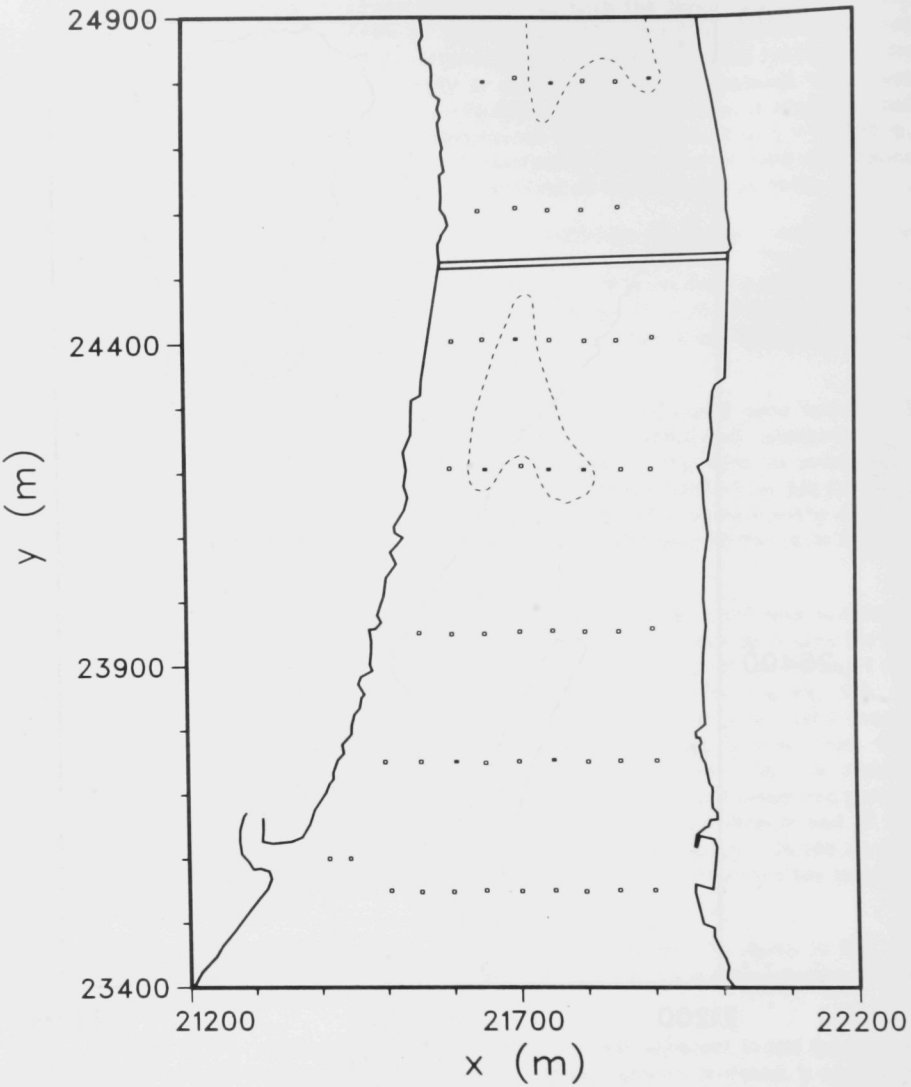

FIGURE 15 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours (if present) for Survey II Downstream of the Savanna Bay Disposal Site

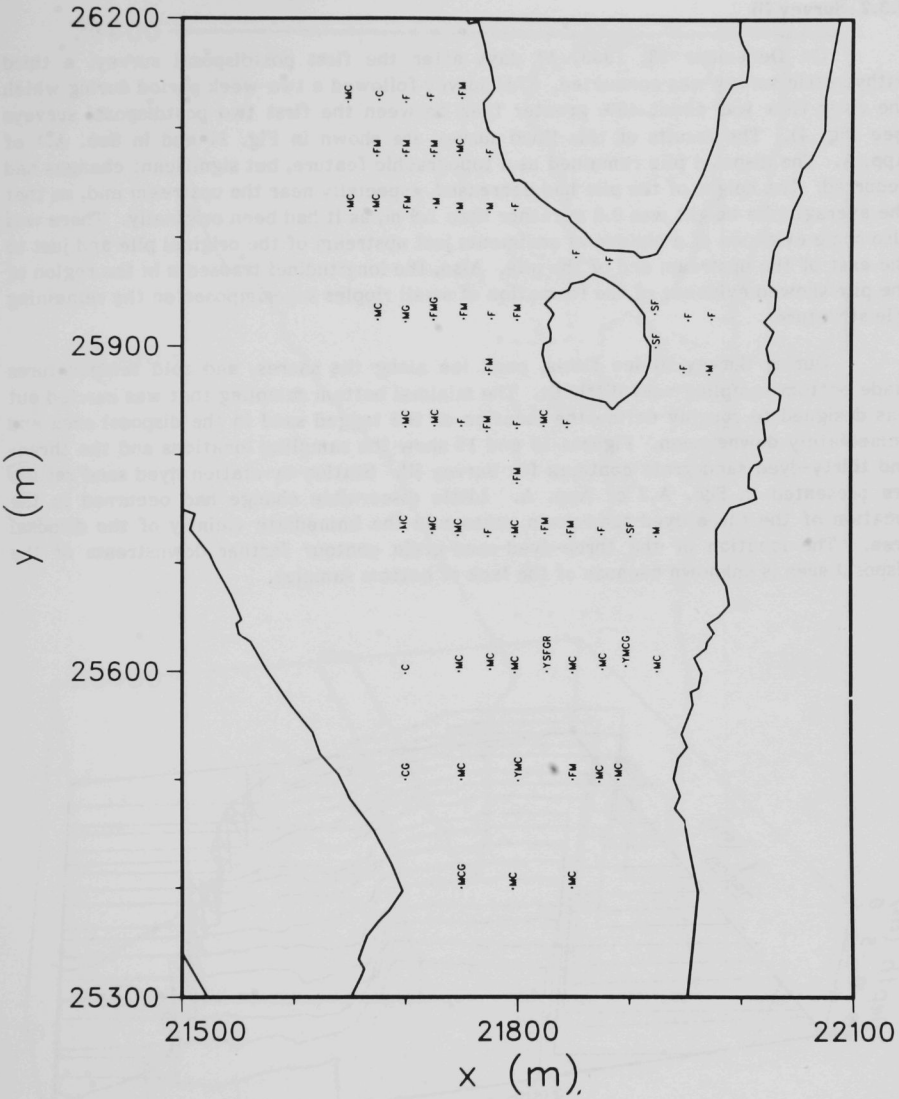

FIGURE 16 Approximate Classification of Bottom Sediments at Sampling Locations for Survey II at the Savanna Bay Disposal Site

3.3.2 Survey III

On December 13, 1983, 47 days after the first postdisposal survey, a third bathymetric survey was conducted. This survey followed a two-week period during which the river flow was about 40% greater than between the first two postdisposal surveys (see Fig. 4). The results of this third survey are shown in Fig. 17 and in Sec. A.1 of App. A. The disposal pile remained as a topographic feature, but significant changes had occurred. The height of the pile had decreased, especially near the upstream end, so that the average pile height was 0.8 m rather than 1.9 m, as it had been originally. There was also some evidence of a buildup of sediments just upstream of the original pile and just to the east of the upstream end of the pile. Also, the longitudinal transects in the region of the pile showed evidence of the formation of small ripples superimposed on the remaining pile structure.

During Survey III ice flows, pack ice along the shores, and cold temperatures made bottom sampling very difficult. The minimal bottom sampling that was carried out was designed to roughly define the location of the tagged sand in the disposal area and immediately downstream. Figures 18 and 19 show the sampling locations and the three- and thirty-dyed-sand-grain contours for Survey III. Station-by-station dyed sand results are presented in Sec. A.2 of App. A. Little discernible change had occurred in the location of the three-dyed-sand-grain contour in the immediate vicinity of the disposal area. The location of the three-dyed-sand-grain contour farther downstream of the disposal area is unknown because of the lack of bottom samples.

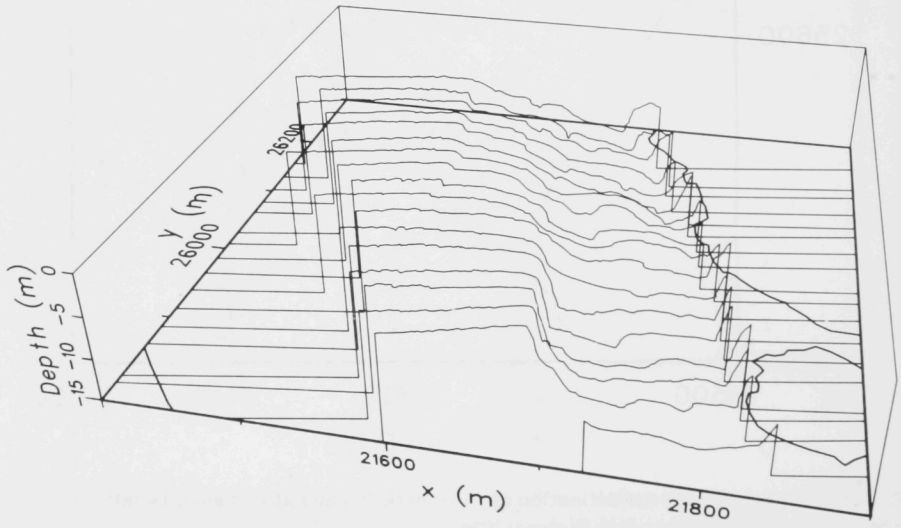

FIGURE 17 Perspective Plot of Transverse Bathymetric Transects for Survey III at the Savanna Bay Disposal Site

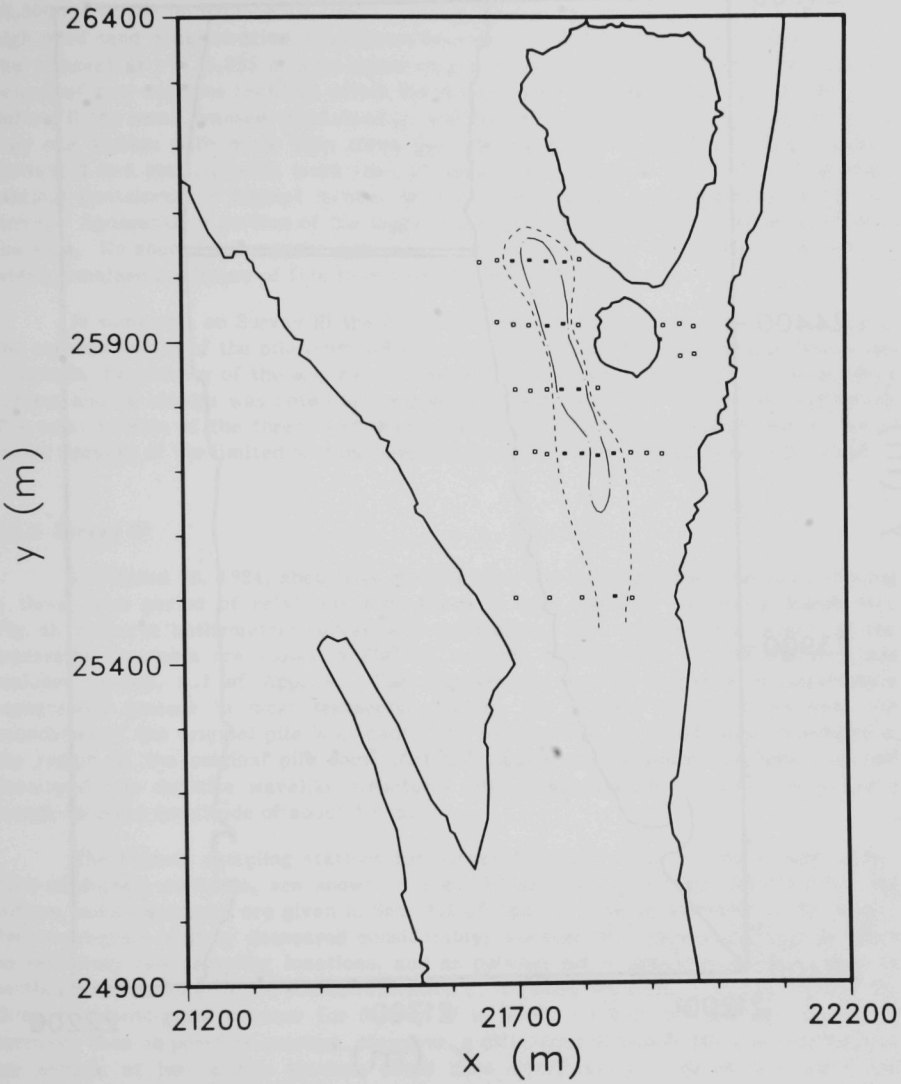

FIGURE 18 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours for Survey III at the Savanna Bay Disposal Site

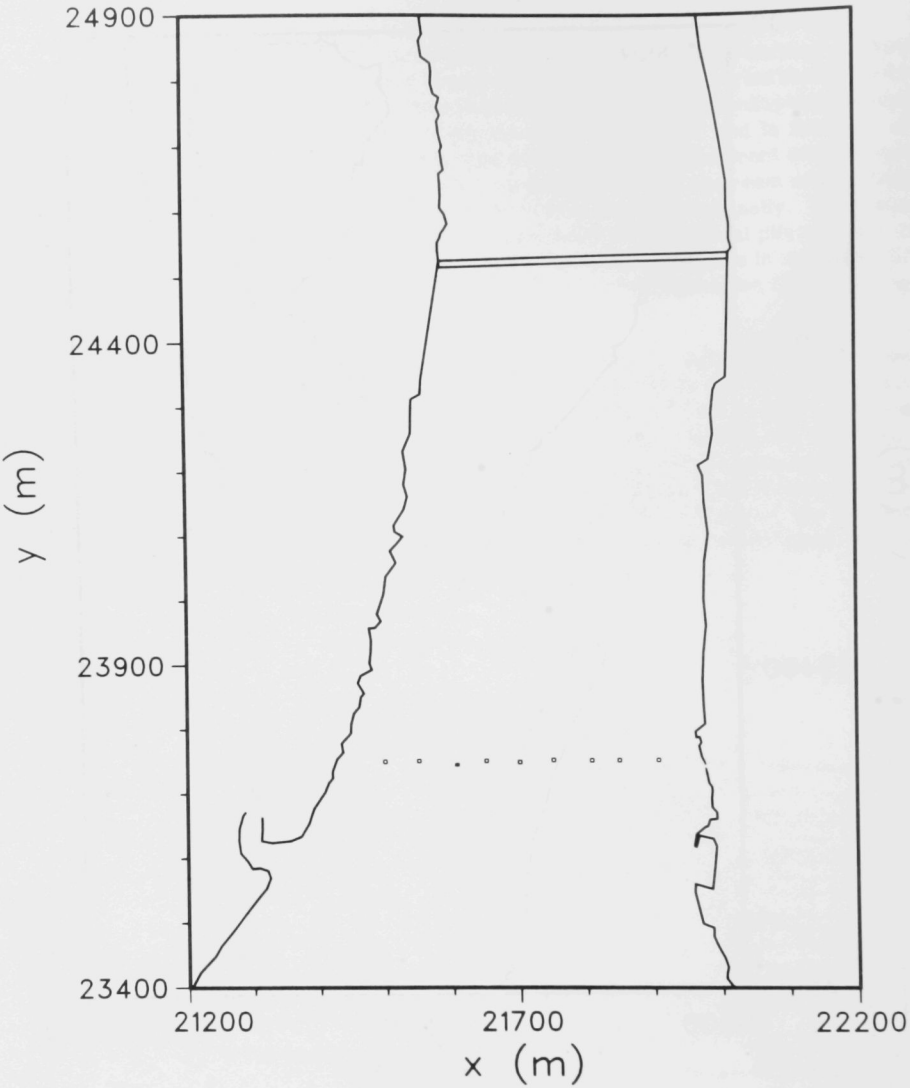

FIGURE 19 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours (if present) for Survey III Downstream of the Savanna Bay Disposal Site

The thirty-dyed-sand-grain contour on Survey III enclosed an area of about 16,000 m^2 in the immediate disposal area, but the existence of any downstream areas of high dyed sand concentration is unknown because of the lack of samples. Results from the transect at y = 25,825 m were again very interesting. During Survey I that transect contained four stations that fell within the thirty-dyed-sand-grain contour. However, on Survey II the same transect contained no stations with 30 or more dyed sand grains and only one station with more than three dyed sand grains. By Survey III that transect contained two stations with more than 30 dyed sand grains; furthermore, one of those stations contained the highest number of dyed sand grains per sample observed on the survey. Apparently a portion of the tagged sand from the disposal pile had migrated into the area. No change was apparent in the general classification of the bottom sediments, which remained a mixture of fine to coarse sand (see Fig. 20).

In summary, on Survey III the only significant change observed was a decrease in the average height of the pile from 1.9 m to 0.8 m. The number of dyed sand grains per sample in the vicinity of the original disposal site was about the same as on the previous survey, and no change was noted in the general classification of the bottom sediments. The total extents of the three- and thirty-dyed-sand-grain contours could not be determined because of the limited bottom sampling caused by winter conditions on the river.

3.3.3 Survey IV

On March 28, 1984, about five months after the dredging operation and following a three-week period of relatively high flows in late February and early March (see Fig. 4), a fourth bathymetric survey was conducted. The results from several of the transverse transects are shown in Fig. 21, and the results from all the transects are included in Sec. A.1 of App. A. The disposal pile was no longer a distinguishable topographic feature in most transects. Again, the buildup of sediments near the boundaries of the original pile is evident. The results from the longitudinal transects in the region of the original pile show that the ripples that appeared in Survey III had developed into definite wavelike structures with a wavelength of about 15 m and a trough-to-crest amplitude of about 0.8 m.

The bottom sampling stations for Survey IV, along with the three- and thirty-dyed-sand-grain contours, are shown in Figs. 22 and 23. Complete results from the bottom sampling survey are given in Sec. A.2 of App. A. The areal extent of the three-dyed-sand-grain contour decreased considerably; however, this apparent change is based on relatively few sampling locations, and as pointed out in previous sections, may be partially attributable to the coarse resolution of the sampling grid. The total area of the three-dyed-sand-grain contour for Survey IV is about 110,000 m^2, and the contour is narrower than on previous surveys. However, a difference of one or two dyed sand grains per sample at just a few stations could have significantly affected the width and therefore the area of the contour, especially in the downstream region of the contour. Basically, the extent of the three-dyed-sand-grain contour at the Savanna Bay site is so large that it would have been impractical to sample with a resolution adequate to define the contour to the same degree of accuracy that was attainable at the Gordon's Ferry and Whitney Island sites.

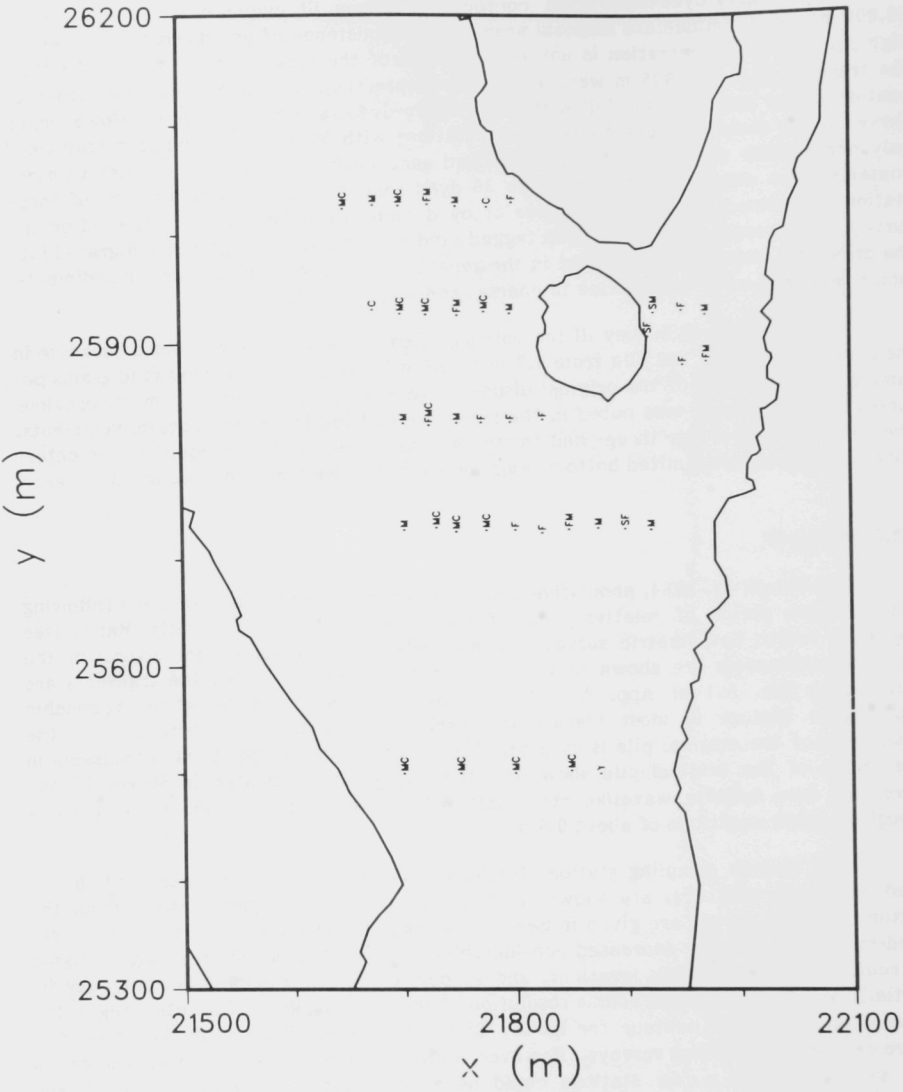

FIGURE 20 Approximate Classification of Bottom Sediments at Sampling Locations for Survey III at the Savanna Bay Disposal Site

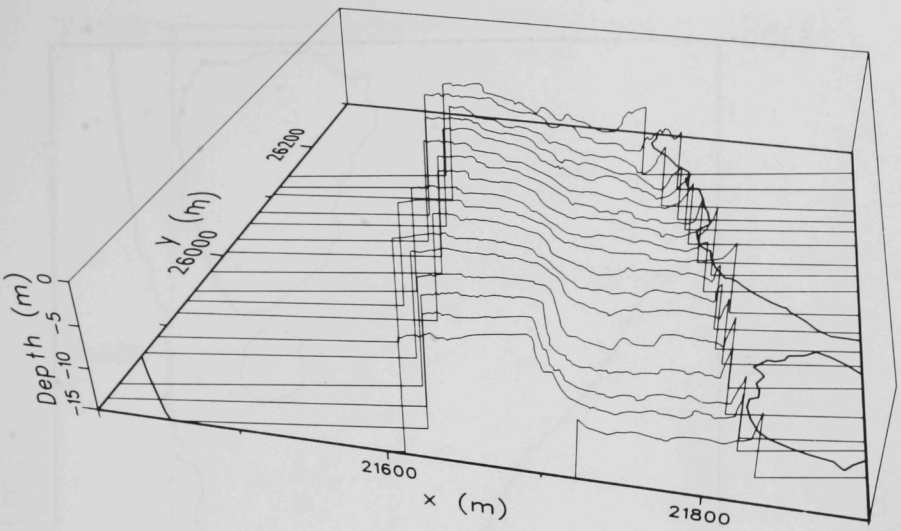

FIGURE 21 Perspective Plot of Transverse Bathymetric Transects for Survey IV at the Savanna Bay Disposal Site

The location and extent of the thirty-dyed-sand-grain contour in the disposal area are almost identical to those on the previous survey. The area within the contour is about 18,000 m^2. The region near the downstream side of the deep hole at about y = 25,200 m, that in previous surveys (except the winter survey when samples were not collected there) included one or two stations with more than 30 dyed sand grains, did not yield any samples with anywhere near that number on Survey IV. However, as is apparent in Fig. 22, the region was not sampled very extensively. No change in the classification of bottom sediments (see Fig. 24) was apparent, with the bottom material remaining a mixture of fine to coarse sand.

The only significant change found on Survey IV was revealed by the bathymetric survey. The original pile was no longer distinguishable on most of the lateral transects, and wavelike bottom structures with an approximate wavelength of 15 m and an amplitude of 0.8 m were apparent on the longitudinal transects. Within the resolution of the sampling grid, no change was discernable in the size and location of the three-dyed-sand-grain contour or of the thirty-dyed-sand-grain contour in the disposal area; however, the thirty-dyed-sand-grain contour that previously existed on the downstream side of the deep hole about 800 m downstream of the original disposal area was not apparent on Survey IV. No change occurred in the classification of bottom sediments.

3.3.4 Survey V

Following an extended period of high flows from April through July, a fifth bathymetric survey was conducted on August 1, 1984, just over nine months after the

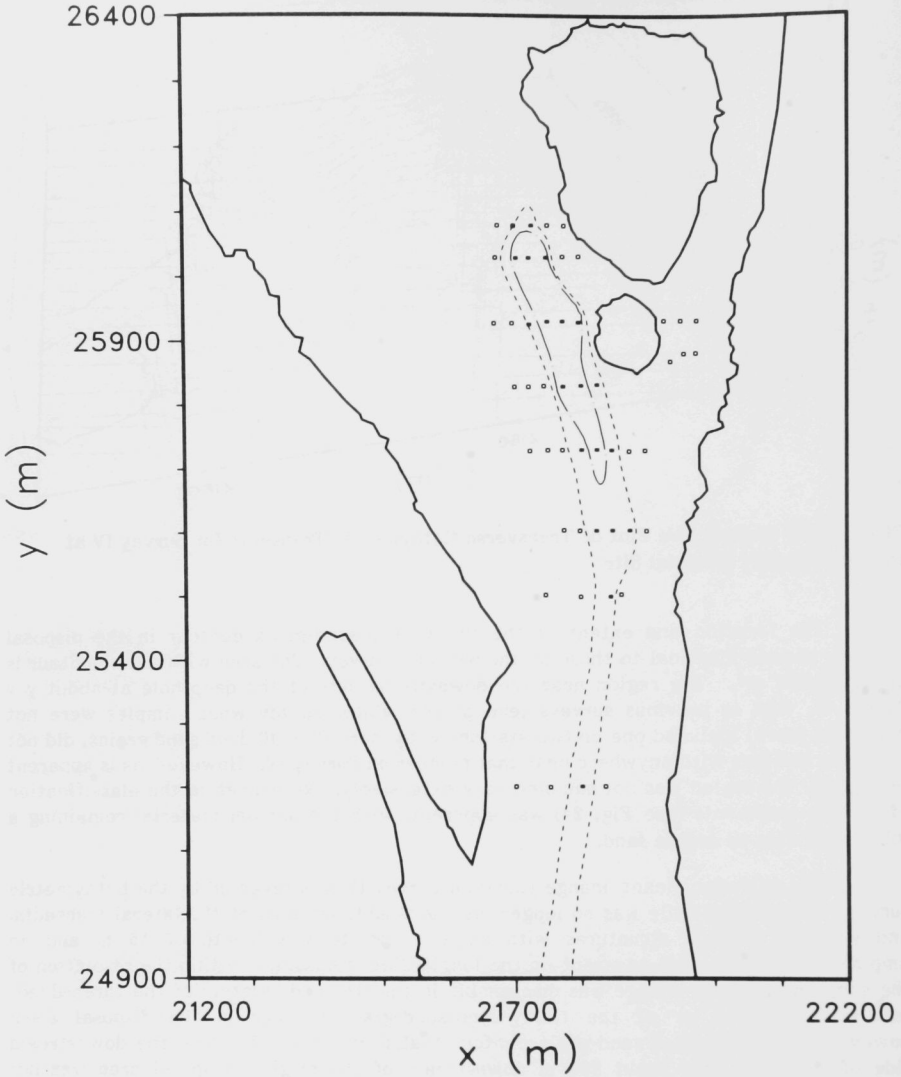

FIGURE 22 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours for Survey IV at the Savanna Bay Disposal Site

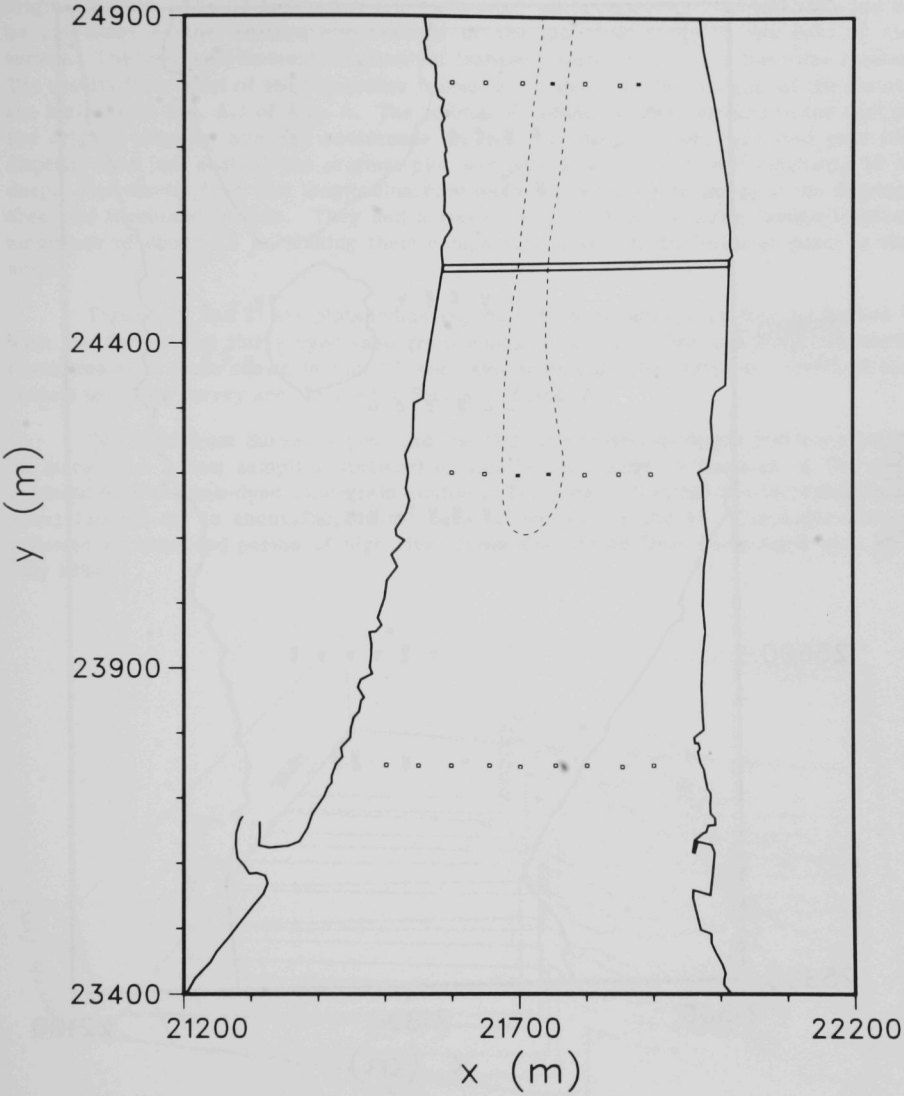

FIGURE 23 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours (if present) for Survey IV Downstream of the Savanna Bay Disposal Site

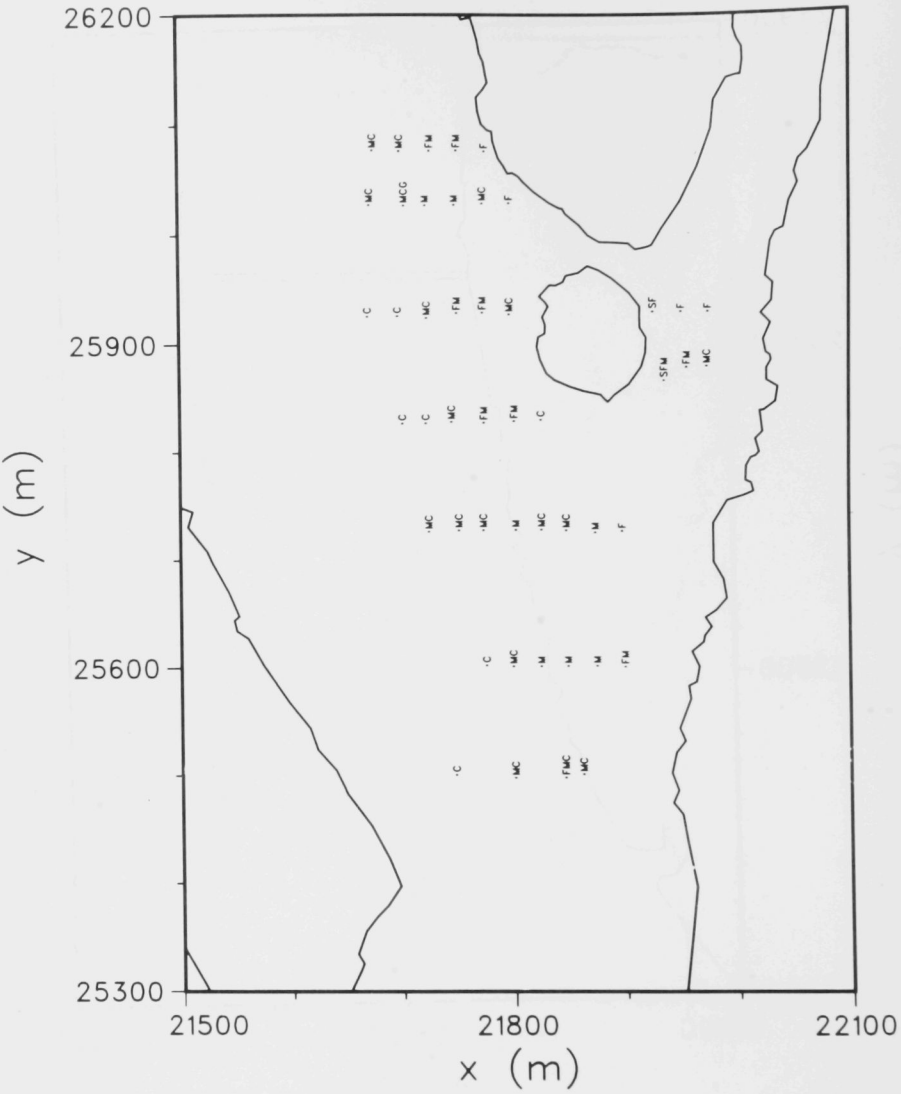

FIGURE 24 Approximate Classification of Bottom Sediments at Sampling Locations for Survey IV at the Savanna Bay Disposal Site

original survey. The 23 transverse transects were again repeated, although they had to be cut short at the western end because of the low river stage on the date of the survey. The two westernmost longitudinal transects were omitted for the same reason. The results from most of the transverse transects are shown in Fig. 25, and all the results are included in Sec. A.1 of App. A. The buildup of sediments upstream and to the east of the original disposal pile had continued. In fact, the deep channel that runs past the disposal area just east of the original pile was only 9 m deep. It was originally 10 m deep. The results from the longitudinal transects showed that the dunes in the disposal area had increased in size. They had a wavelength of 30-50 m and a trough-to-crest amplitude of about 1.5 m, making them comparable in size to the original dunes in the area.

Figures 26 and 27 are plots indicating the bottom sampling locations for Survey V with the three- and thirty-dyed-sand-grain contours drawn. Two additional transects downstream of those shown in Fig. 27 were also sampled. The complete results of the bottom sampling survey are included in Sec. A.2 of App. A.

The data from Survey V provided the first substantial evidence (evidence based on more than a few sampling stations) of significant change in the size of the area enclosed by the three-dyed-sand-grain contour. The area of that contour increased from about 110,000 m^2 to about 283,000 m^2 between Surveys IV and V. This major change followed an extended period of high river flows that lasted from early April until late July 1984.

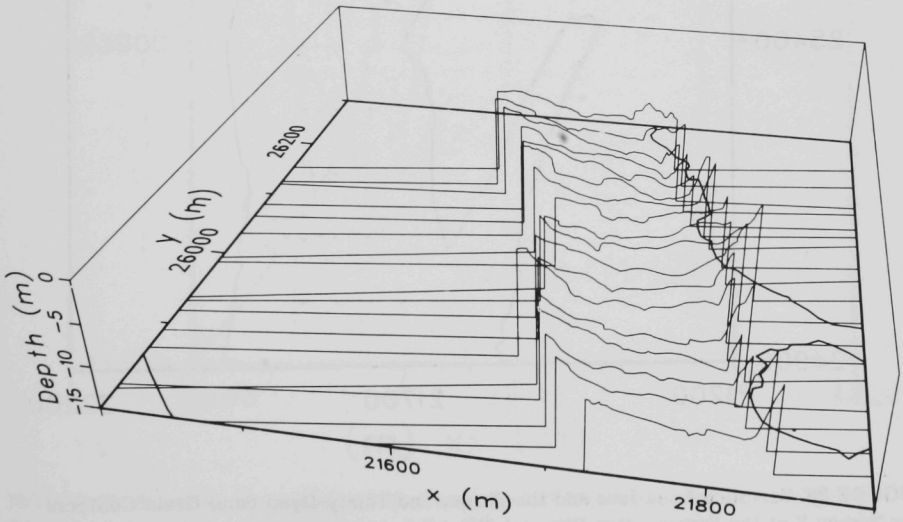

FIGURE 25 Perspective Plot of Transverse Bathymetric Transects for Survey V at the Savanna Bay Disposal Site

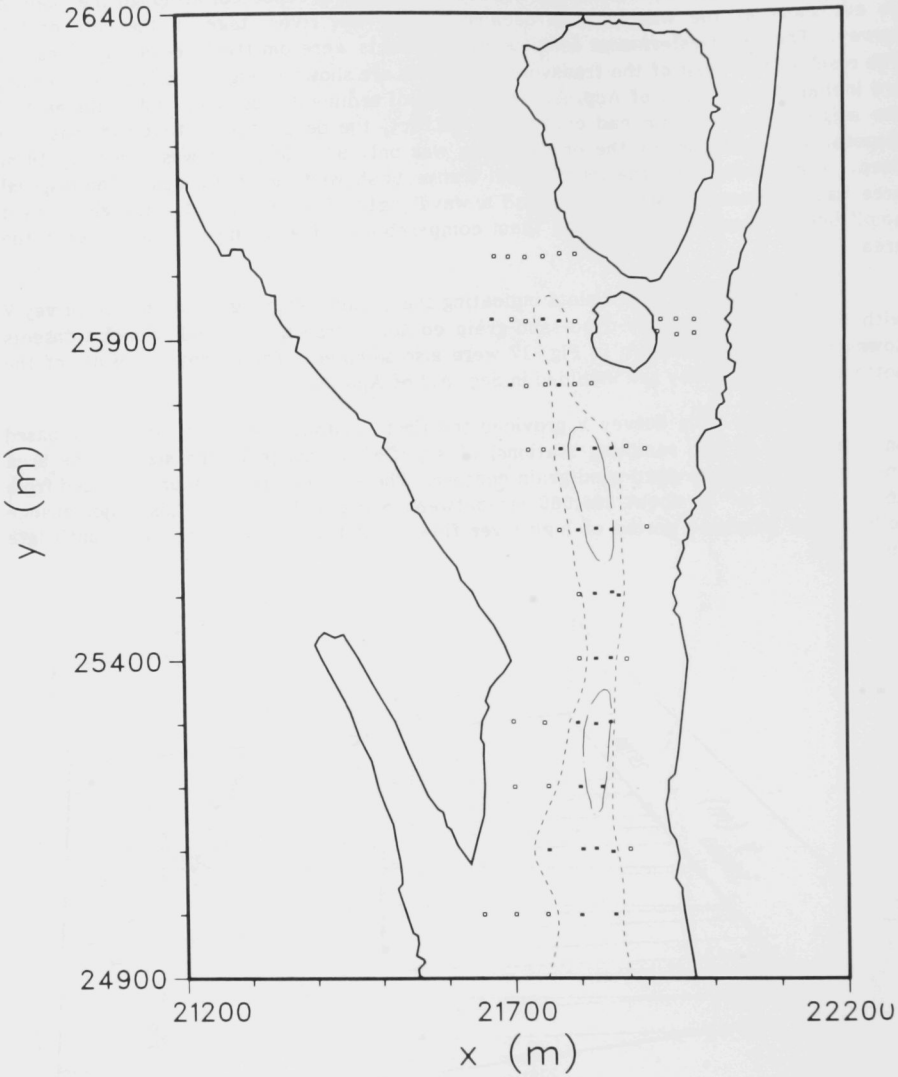

FIGURE 26 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours for Survey V at the Savanna Bay Disposal Site

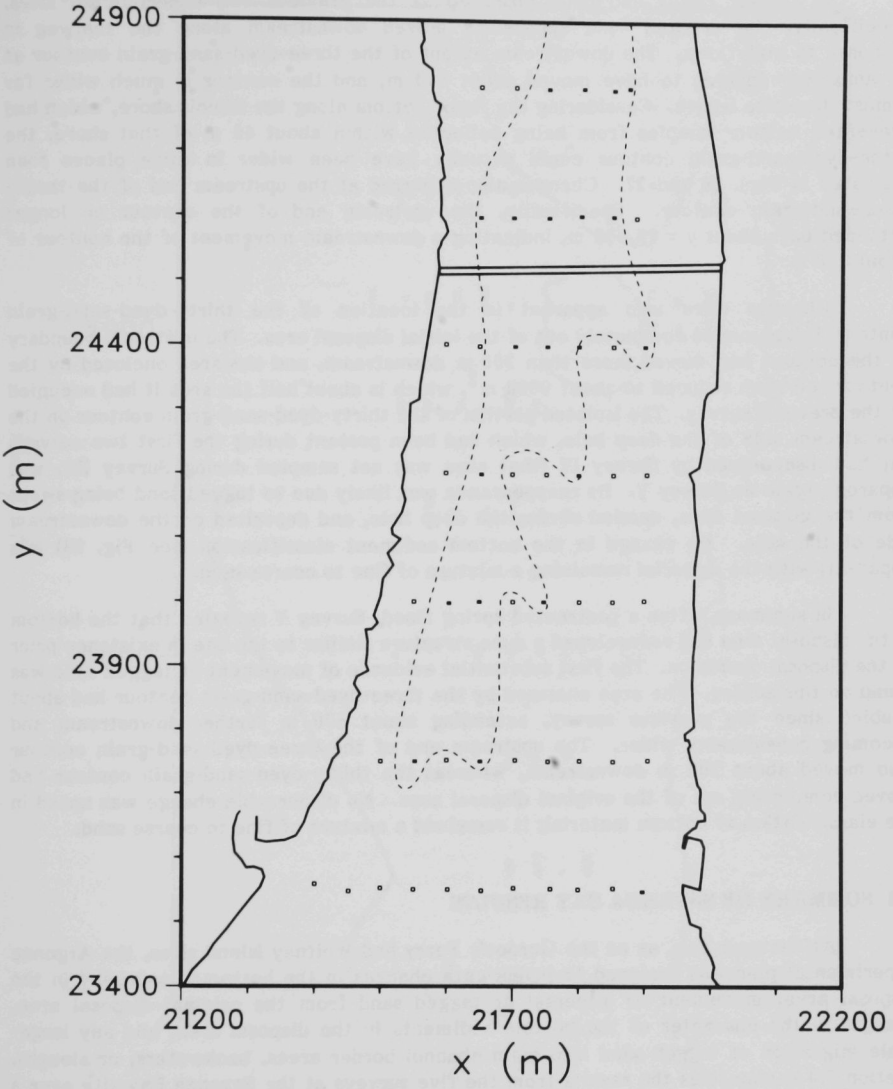

FIGURE 27 Sampling Locations and the Three- and Thirty-Dyed-Sand-Grain Contours (if present) for Survey V Downstream of the Savanna Bay Disposal Site

A similar result had been observed at the previous two experimental sites. Specifically, the dredged sand apparently moved downstream along the thalweg in response to high flows. The downstream extent of the three-dyed-sand-grain contour at Savanna Bay appears to have moved about 500 m, and the contour is much wider for almost its entire length. Considering the rocky bottom along the Illinois shore, which had prevented bottom samples from being collected within about 40 m of that shore, the three-dyed-sand-grain contour could actually have been wider in some places than indicated in Figs. 26 and 27. Changes also occurred at the upstream end of the three-dyed-sand-grain contour. Specifically, the upstream end of the contour no longer extended past about y = 25,950 m, indicating a downstream movement of the contour of about 150 m.

Changes were also apparent in the location of the thirty-dyed-sand-grain contour; it had moved completely out of the initial disposal area. The upstream boundary of the contour had moved more than 300 m downstream, and the area enclosed by the contour had been reduced to about 9000 m^2, which is about half the area it had occupied on the previous survey. The isolated portion of the thirty-dyed-sand-grain contour on the downstream side of the deep hole, which had been present during the first two surveys but had disappeared by Survey IV (that area was not sampled during Survey III), was apparent again on Survey V. Its reappearance was likely due to tagged sand being swept from the disposal area, carried across the deep hole, and deposited on the downstream side of the hole. No change in the bottom sediment classification (see Fig. 28) was apparent, with the material remaining a mixture of fine to coarse sand.

In summary, after a protracted spring flood, Survey V revealed that the bottom in the disposal area had redeveloped a dune structure similar to the one in existence prior to the disposal operation. The first substantial evidence of movement of tagged sand was found on this survey. The area enclosed by the three-dyed-sand-grain contour had about doubled since the previous survey, extending about 500 m farther downstream and becoming considerably wider. The upstream end of the three-dyed-sand-grain contour also moved about 200 m downstream, whereas the thirty-dyed-sand-grain contour had moved completely out of the original disposal area. No discernable change was noted in the classification of bottom material; it remained a mixture of fine to coarse sand.

3.4 SUMMARY OF SAVANNA BAY RESULTS

At Savanna Bay, as at the Gordon's Ferry and Whitney Island sites, the Argonne experimental plan was designed to investigate changes in the bottom topography in the disposal area, movement or dispersal of tagged sand from the original disposal area, changes in the character of the bottom sediments in the disposal area, and any large-scale migration of tagged sand into main-channel border areas, backwaters, or sloughs. Section 3.4 summarizes the results from the five surveys at the Savanna Bay site over a nine-month period following disposal.

The bottom topography at Savanna Bay evolved from a series of overlapping mounds to a dune-covered bottom, which was similar in form to the bottom prior to disposal. No change was noted on Survey II (10 days after disposal). However, by Survey III (47 days after disposal), the height of the pile had decreased from an average height of

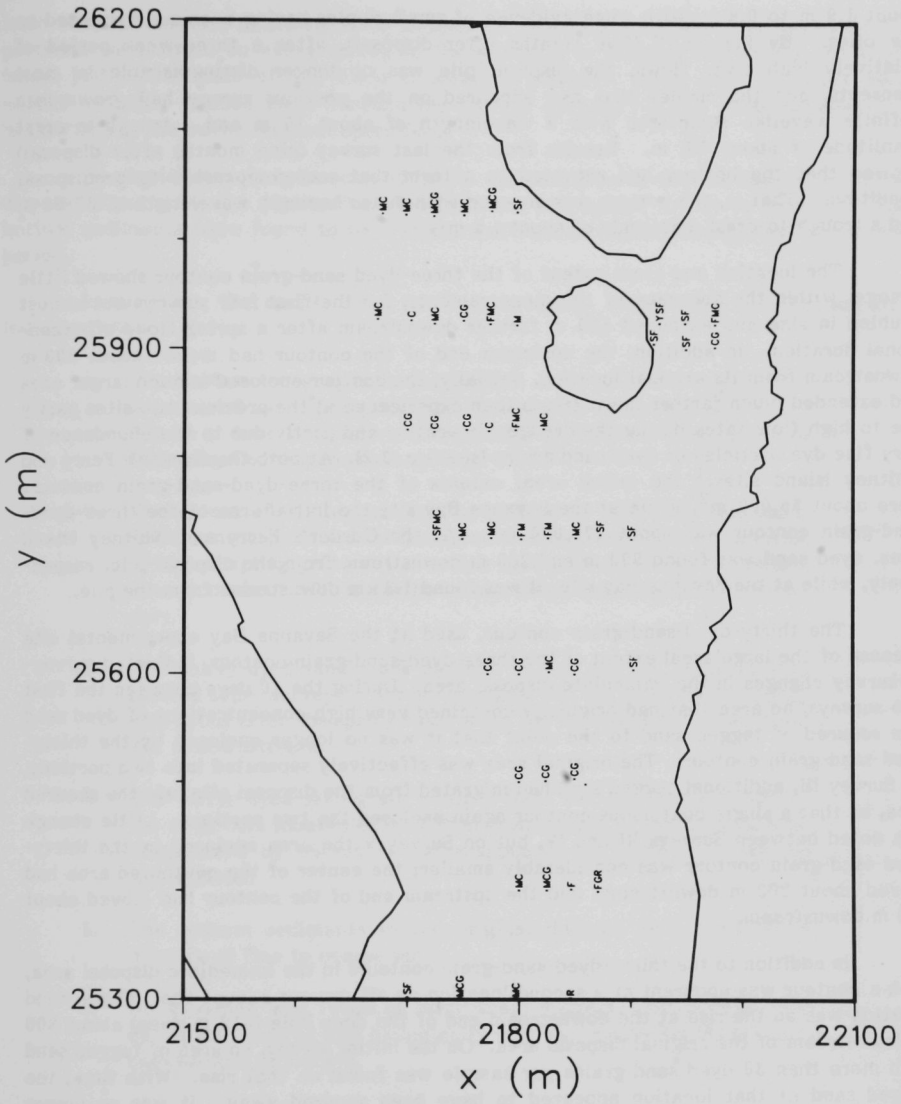

FIGURE 28 Approximate Classification of Bottom Sediments at Sampling Locations for Survey V at the Savanna Bay Disposal Site

about 1.9 m to 0.8 m, with some evidence of small ripples having been superimposed on the piles. By Survey IV (five months after disposal), after a three-week period of relatively high river flows, the disposal pile was no longer distinguishable in most transects, and the ripples that had appeared on the previous survey had grown into definite wavelike structures with a wavelength of about 15 m and a trough-to-crest amplitude of about 0.8 m. Results from the last survey (nine months after disposal) showed that the bottom had returned to a form that was comparable to predisposal conditions. That is, the bottom was covered with dunes having a wavelength of 30-50 m and a trough-to-crest amplitude of about 1.5 m.

The location and areal extent of the three-dyed-sand-grain contour showed little change, within the accuracy of the measurements, for the first four surveys but almost doubled in size and extended 500 m farther downstream after a spring flood of exceptional duration. In addition, the upstream end of the contour had moved about 200 m downstream from its original location. Initially, the contour enclosed a much larger area and extended much farther downstream than experienced at the previous two sites partly due to high flow rates during the dredging operation and partly due to the abundance of very fine dye particles or dyed sand grains (see Sec. 3.2). At both the Gordon's Ferry and Whitney Island sites,[1] the initial areal extents of the three-dyed-sand-grain contours were about 55,000 m^2, while at the Savanna Bay site the initial area of the three-dyed-sand-grain contour was about 170,000 m^2. At the Gordon's Ferry and Whitney Island sites, dyed sand was found 500 m and 200 m downstream from the disposal pile, respectively, while at the Savanna Bay site, it was found 1.8 km downstream from the pile.

The thirty-dyed-sand-grain contour, used at the Savanna Bay experimental site because of the large areal extent of the three-dyed-sand-grain contour, indicated survey-to-survey changes in the immediate disposal area. During the 10 days between the first two surveys, an area that had originally contained very high concentrations of dyed sand was scoured of tagged sand to the point that it was no longer enclosed by the thirty-dyed-sand-grain contour. The original area was effectively separated into two portions. By Survey III, additional tagged sand had migrated from the disposal pile into the scoured area, so that a single continuous contour again enclosed the two portions. Little change was noted between Surveys III and IV, but on Survey V the area enclosed by the thirty-dyed-sand-grain contour was considerably smaller; the center of the contoured area had moved about 200 m downstream, and the upstream end of the contour had moved about 300 m downstream.

In addition to the thirty-dyed-sand-grain contours in the immediate disposal area, such a contour was apparent at a second location on all surveys except one. This second location was on the rise at the downstream end of the deep hole (>12 m deep) about 800 m downstream of the original disposal area. On the initial survey, an area of tagged sand with more than 30 dyed sand grains per sample was found on that rise. With time, the tagged sand at that location appeared to have been scoured away. It was no longer apparent by Survey IV. However, after the spring floods, a thirty-dyed-sand-grain contour again appeared in that area. The tagged sand had apparently been swept from an area upstream of the deep hole and deposited on the downstream side of the hole.

As at the previous two experimental sites, no evidence was found that tagged sand had migrated from the thalweg into any biologically sensitive areas such as

main-channel borders, backwaters, or sloughs. A few very tiny dyed sand grains or dye particles were found on every survey in the entrance to Savanna Bay behind the small island just downstream of the disposal location; however, these small particles were almost certainly washed there through the shallow opening (~1.5 m deep) between the islands during the initial disposal operation.

No significant change occurred in the classification of bottom sediments in the disposal area during the 10-month period from the predisposal survey to Survey V. The bottom sediments were found to be a mixture of fine to coarse sand during that entire period.

In summary, the results from the five surveys at the Savanna Bay disposal site indicated that:

1. The bottom topography in the original disposal area changed from a series of overlapping mounds immediately after disposal in the fall to a dune structure similar to the predisposal dune structure following flooding the next spring.

2. The extent of the tagged sand, as defined by the three-dyed-sand-grain contour, showed no measurable change within the resolution of the sampling grid until after the spring flood, when the contour extended about 500 m farther downstream and widened considerably.

3. The thirty-dyed-sand-grain contour in the original disposal area showed some survey-to-survey changes, but the first major change was noted after the spring flood when the contour had moved about 200 m downstream.

4. The thirty-dyed-sand-grain contour near the downstream side of the deep hole located about 800 m downstream of the disposal area disappeared by Survey IV but reappeared on Survey V after the spring flood.

5. The bottom sediments in the original disposal area remained a mixture of fine to coarse sand.

6. No evidence was found of large-scale migration of dredged sand out of the thalweg into biologically sensitive main-channel borders, backwaters, or sloughs.

4 BATHYMETRIC MEASUREMENTS AND RESULTS AT DUCK CREEK

The purpose of the experiment at the Duck Creek site was to create piles of sand in the river thalweg and study their effect on local fish populations. In fact, the dredging at Duck Creek was not required for channel maintenance and was carried out for the sole purpose of creating the piles. A dyed sand tracer was not used at this site because there were no plans to track the movement of the dredged sand. The fish population studies were conducted by the U.S. Fish and Wildlife Service, which has been working with the Rock Island District to investigate the potential impact of thalweg disposal on fisheries. Argonne's primary role at this site was to locate the piles, to estimate their size, and to monitor subsequent changes through periodic bathymetric surveys. The results of these surveys have provided some of the physical data needed by the U.S. Fish and Wildlife Service to interpret the results of their fisheries studies.

Section 4 describes the bathymetric surveys and presents the results from the Duck Creek site. Table 2 lists the important experimental activities at Duck Creek. Because the Duck Creek site is located in the same pool as the Savanna Bay site, the river hydrograph measured at Lock and Dam 13 (see Fig. 4) is pertinent for this site. Figure 29 repeats that hydrograph but indicates the times of the surveys at Duck Creek.

TABLE 2 Experimental Activities at the Duck Creek Site

Experimental Activity	Date	Time after Disposal (days)[a]
Predisposal bathymetry	October 24, 1983	-5
Dredging and disposal operations	October 27-29, 1983	0
Survey I	October 29, 1983	0
Survey II	November 10, 1983	12
Survey III	December 14, 1983	46
Survey IV	March 27, 1984	150
Survey V	August 2, 1984	278

[a]Time from the end of disposal operations on October 29, 1983.

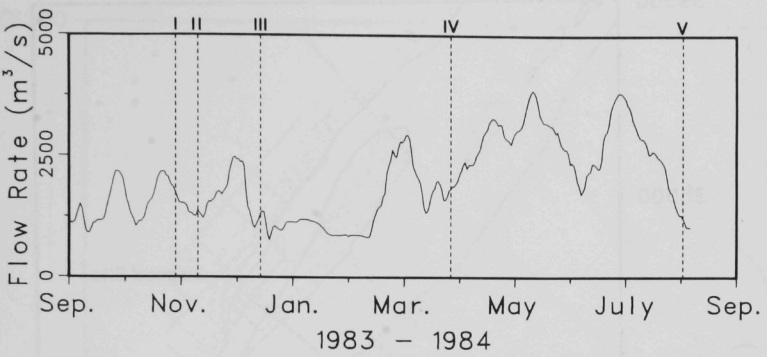

FIGURE 29 Mean Daily River Discharge for the Duck Creek Site as Recorded at Lock and Dam 13, with the Dates of the Surveys Indicated

4.1 PREDISPOSAL BATHYMETRIC SURVEY

On October 24, 1983, a bathymetric survey was conducted in the disposal area (see Fig. 30) to characterize the natural bottom topography and to serve as a basis for identifying the disposal piles after the dredging operation. A series of 15 transverse (across-river) transects about 300 m long and 50 m apart were established at the site. In addition, seven longitudinal (along-river) transects about 750 m long were established. These transects were 25 m apart in the region of the thalweg and 50 m apart in the shallower region toward the Illinois shore. Figure 31 shows the locations of the bathymetric transects. The complete results from all the bathymetric transects are found in App. B.

The results from most of the transverse transects are shown in Fig. 32 in the form of a perspective plot, with the base of the plot taken arbitrarily at a depth of 10 m. The direction of flow of the river is from the top to the bottom of the plot. The river is about 400 m wide in this reach, and the thalweg is about 100 m from the Iowa shore. The thalweg region is about 100 m wide and 8.5 m deep. The results for the middle three longitudinal transects, those nearest the proposed disposal area, are presented in Fig. 33, with the transect closest to the Illinois shore at the top. The individual profiles are plotted starting from the downstream end of each transect. Irregular dune structures with trough-to-crest amplitudes of 1-2 m are apparent in the first of these longitudinal transects as well as in the other longitudinal transects toward the Illinois shore (see App. B). However, the bottom is quite flat in the thalweg where the disposal piles were to be placed.

Dredging at the Duck Creek site by the *Thompson* took place on October 27-29, 1983. Sand was dredged from the relatively shallow area toward the Illinois shore and upstream of the site. Three adjacent but distinct disposal piles were created along a 350-m reach of the thalweg.

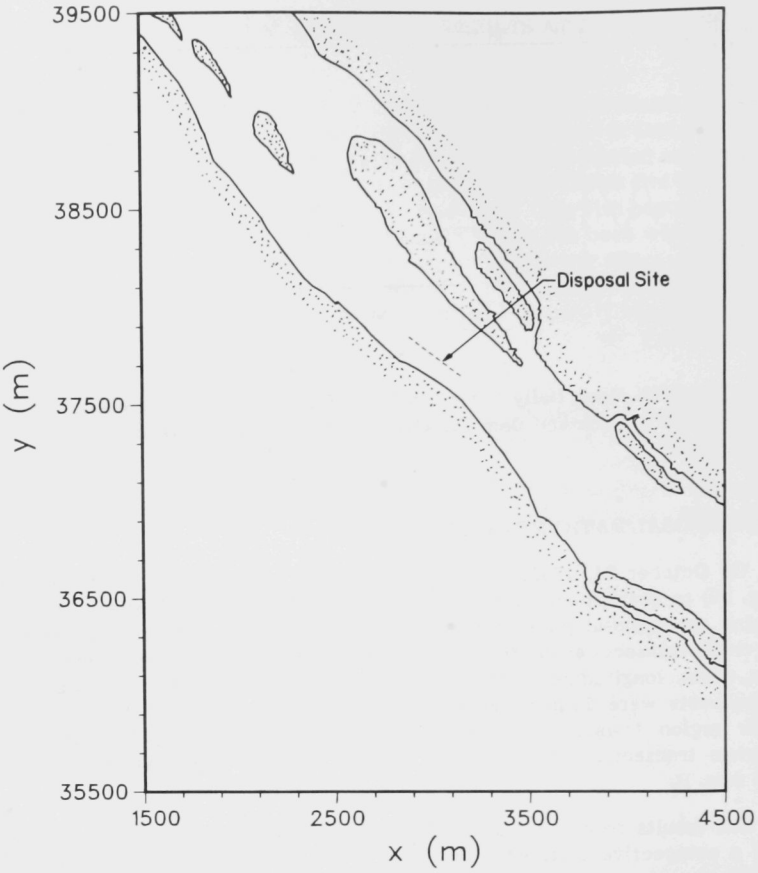

FIGURE 30 Map of Duck Creek Site Showing Disposal Area

4.2 FIRST POSTDISPOSAL BATHYMETRIC SURVEY — SURVEY I

On the afternoon of October 29, 1983, immediately following the dredging operation, another bathymetric survey (Survey I) was conducted. Although the same 15 transverse transects used in the predisposal survey were followed as closely as possible, they did not coincide exactly because of the difficulty in maintaining a specific boat course in the presence of river currents and winds. However, corresponding transects were typically within 5-10 m of each other. Even so, detailed comparisons between corresponding transects may not be valid.

To improve the resolution in the region of the disposal piles, eight transverse transects were added between the original transects, resulting in a spacing of 25 m. The

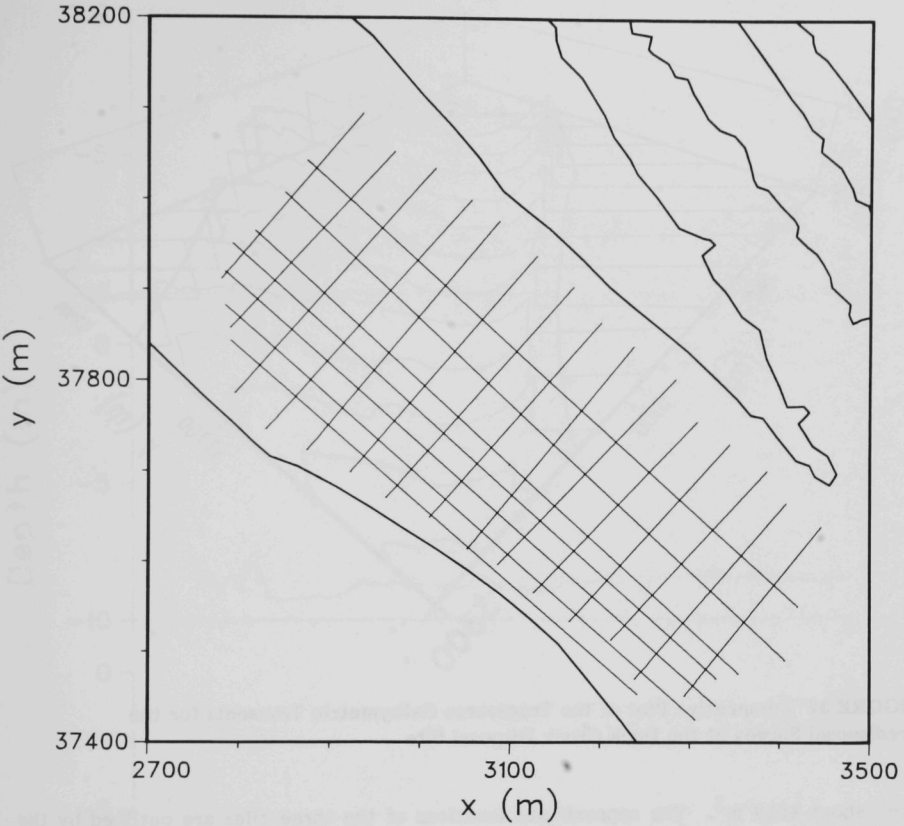

FIGURE 31 Location of Bathymetric Transects for the Predisposal Survey at the Duck Creek Disposal Site

longitudinal transects were also repeated, and two transects were added. Figure 34 shows the locations of the bathymetric transects for this survey.

The results from most of the transverse transects are shown in Fig. 35 in the form of a perspective plot, and the complete results of the survey are presented in App. B. Careful analysis of the bathymetric data shows that three fairly distinct piles were present along a 350-m stretch of the thalweg. The pile farthest downstream was centered at about x = 3080 m and y = 37,690 m. It was about 150 m long, 65 m wide, and 3.2 m high near the center. Its volume is estimated to have been about 15,000 m^3. The center of the middle pile was located near x = 2980 m and y = 37,760 m. It had the form of an 80-m-diameter mound about 2.0 m high near the center, with an estimated volume of 6500 m^3. The pile farthest upstream was centered at about x = 2890 m and y = 37,820 m. It was about 80 m long, 50 m wide, and 1.9 m high. Its volume is estimated to have

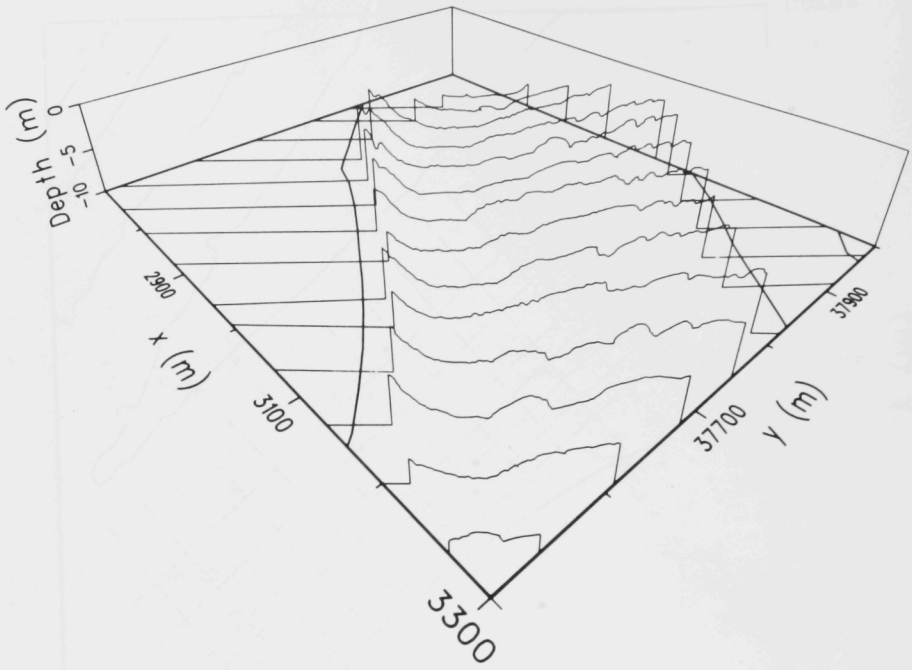

FIGURE 32 Perspective Plot of the Transverse Bathymetric Transects for the Predisposal Survey at the Duck Creek Disposal Site

been about 4000 m^3. The approximate locations of the three piles are outlined by the dashed curves in Fig. 34.

The results from Survey I for the same three longitudinal bathymetric transects shown in Fig. 33 are shown in Fig. 36. The disposal piles are distinguishable in all three transects but are particularly evident in the middle transect.

4.3 SUBSEQUENT BATHYMETRIC SURVEYS

4.3.1 Survey II

On November 10, 1983, 12 days after the first postdisposal survey, another bathymetric survey was made, which followed the transects used in Survey I as closely as possible. Some of the results for the survey are shown in Fig. 37, and the complete results are given in App. B. The disposal piles were still obvious topographic features with little systematic change from Survey I.

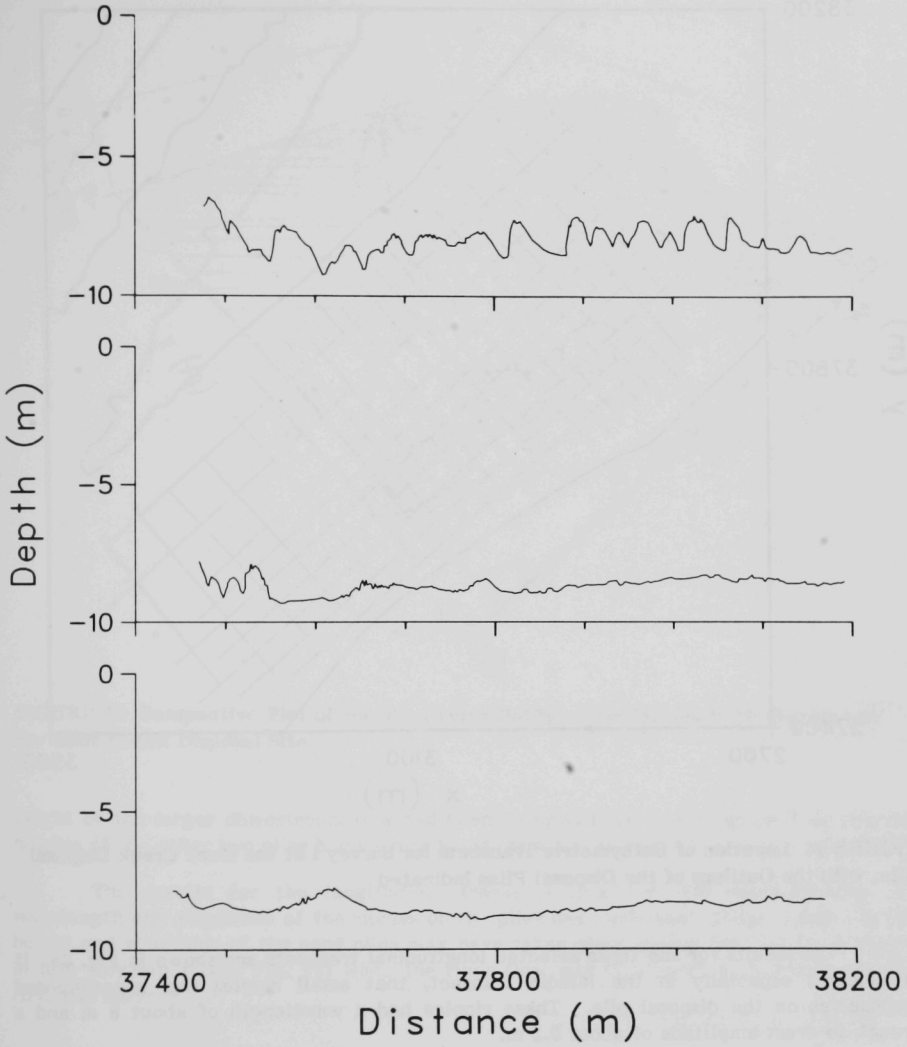

FIGURE 33 Selected Longitudinal Bottom Profiles for the Predisposal Survey at the Duck Creek Disposal Site

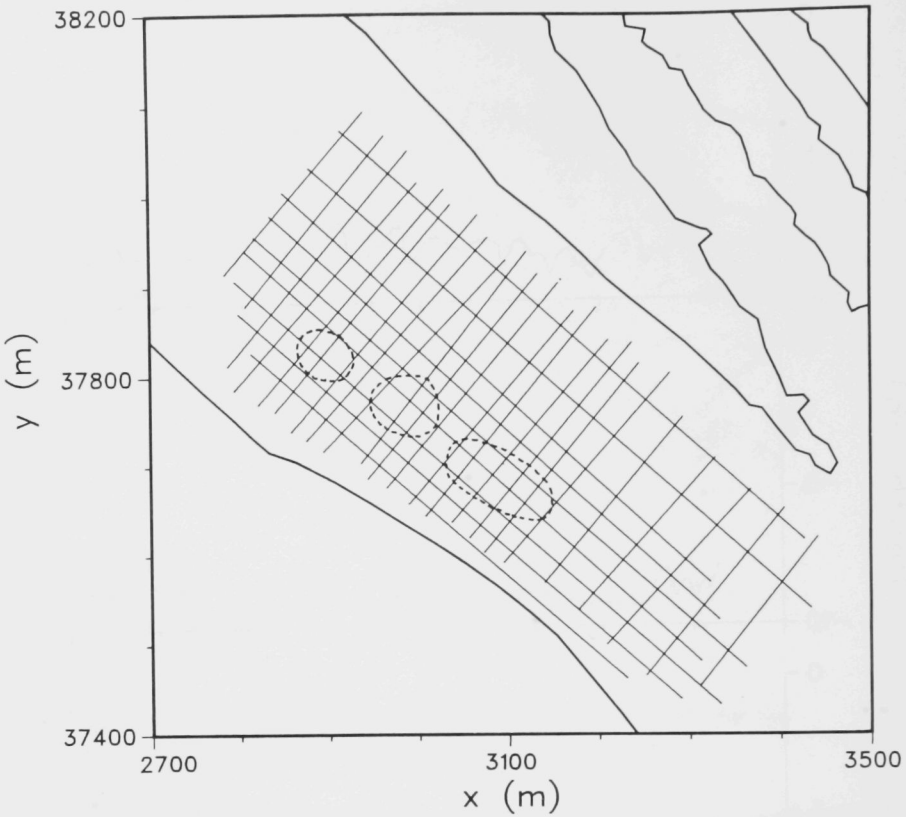

FIGURE 34 Location of Bathymetric Transects for Survey I at the Duck Creek Disposal Site, with the Outlines of the Disposal Piles Indicated

The results for the three selected longitudinal transects are shown in Fig. 38. It is evident, especially in the middle transect, that small ripples had superimposed themselves on the disposal pile. These ripples had a wavelength of about 8 m and a trough-to-crest amplitude of about 0.3 m.

4.3.2 Survey III

On December 14, 1983, 46 days after the first postdisposal survey, a third bathymetric survey was made. Some of the results are shown in Fig. 39, and the complete results are presented in App. B. The figure provides evidence of the disposal piles in many of the transverse transects, but significant changes had taken place. The

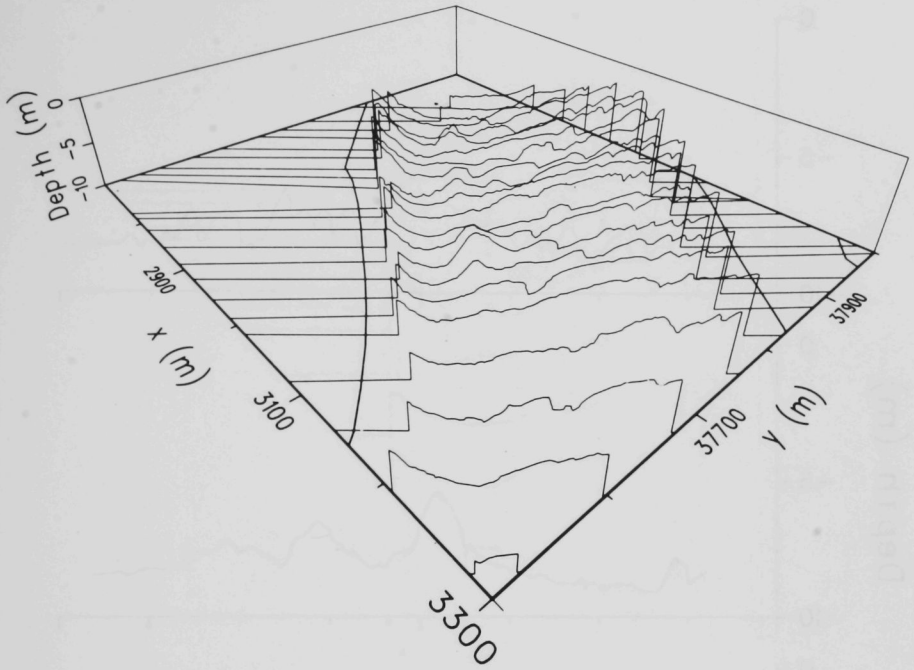

FIGURE 35 Perspective Plot of the Transverse Bathymetric Transects for Survey I at the Duck Creek Disposal Site

height of the larger downstream pile had been reduced from 3 m to about 2 m, and the heights of the other two piles had been reduced from 2 m to about 1 m.

The results for the longitudinal transects (see Fig. 40) revealed that the wavelength and amplitude of the ripples on the piles had increased. These changes in the height and structure of the sand piles may have taken place during the two-week period in late November (see Fig. 29) when the river flow was 40% greater than between the first two surveys.

4.3.3 Survey IV

On March 27, 1984, about five months after the dredging operation and following a three-week period of relatively high flows in late February and early March (see Fig. 29), a fourth bathymetric survey was conducted. The complete results are presented in App. B. Figure 41 shows the results from some of the transverse transects in the form of a perspective plot. The piles could still be vaguely distinguished, but they had been dramatically changed from their original size and shape.

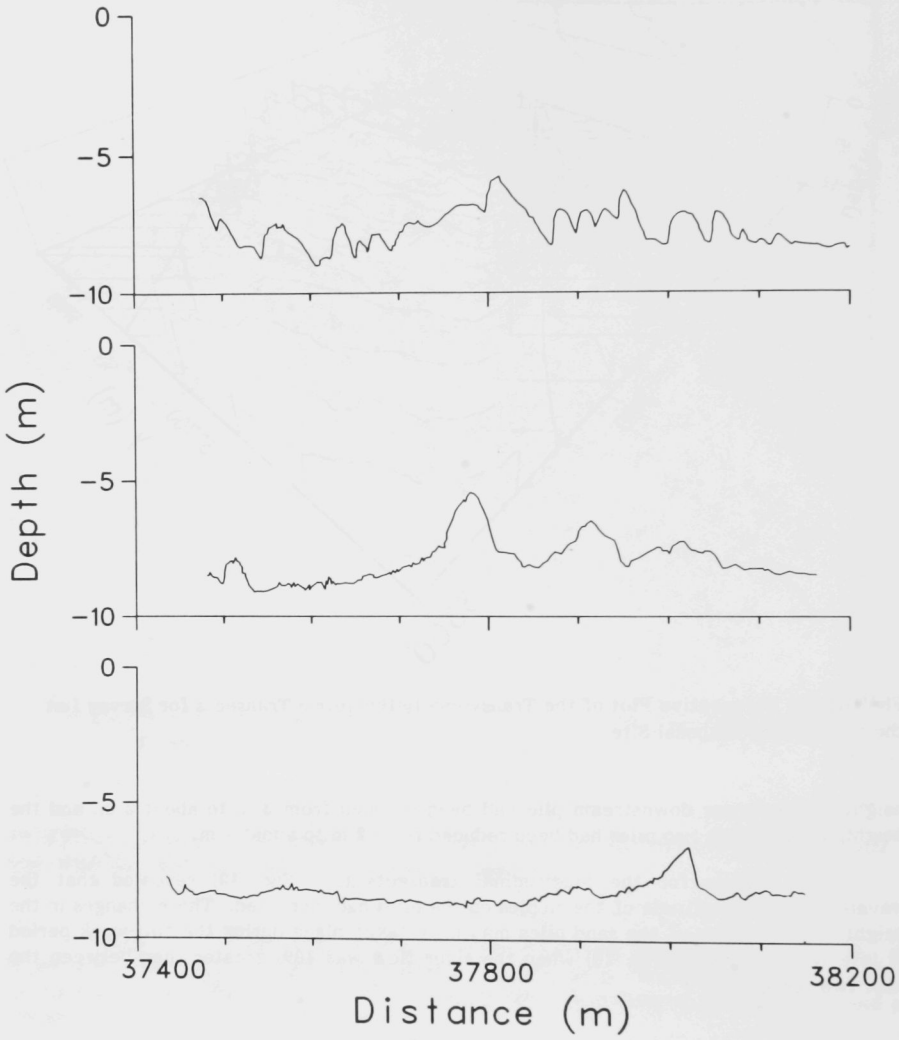

FIGURE 36 Selected Longitudinal Bottom Profiles for Survey I at the Duck Creek Disposal Site

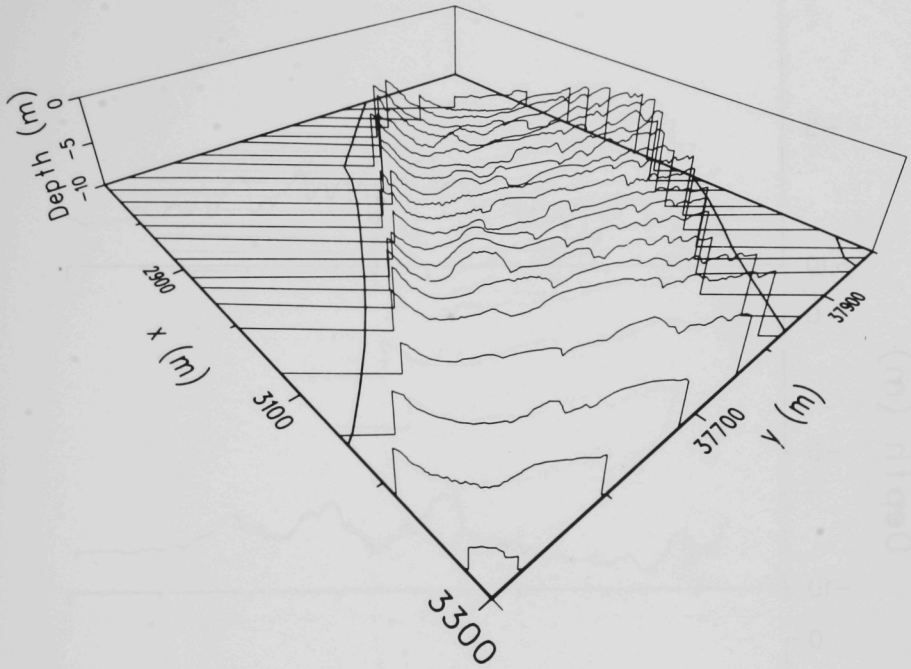

FIGURE 37 Perspective Plot of the Transverse Bathymetric Transects for Survey II at the Duck Creek Disposal Site

Figure 42, which gives the results for the longitudinal transects, shows that fairly regular sand dunes, with a wavelength of about 40 m and a trough-to-crest amplitude of 1.0-1.5 m, had developed in the area of the disposal piles. What remained of the original piles was generally masked by this dune structure.

4.3.4 Survey V

Following an extended period of high flows from April through July (see Fig. 29), a fifth bathymetric survey was conducted on August 2, 1984, just over nine months after the disposal operation. Some of the results are shown in Fig. 43, and the complete results are presented in App. B. No evidence of the pile remained. In fact, Fig. 44, which presents the results from the selected longitudinal transects, shows that the dunes that had developed in the disposal area had disappeared and that the thalweg had essentially returned to its original flat configuration.

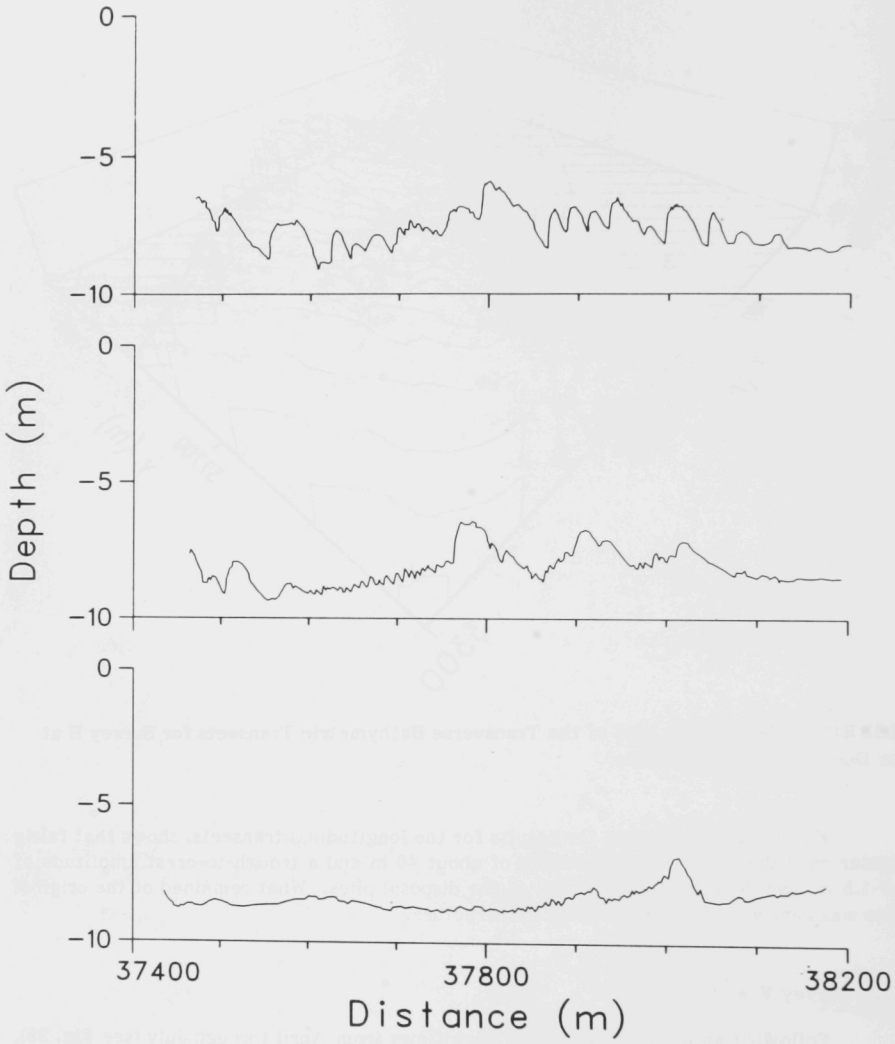

FIGURE 38 Selected Longitudinal Bottom Profiles for Survey II at the Duck Creek Disposal Site

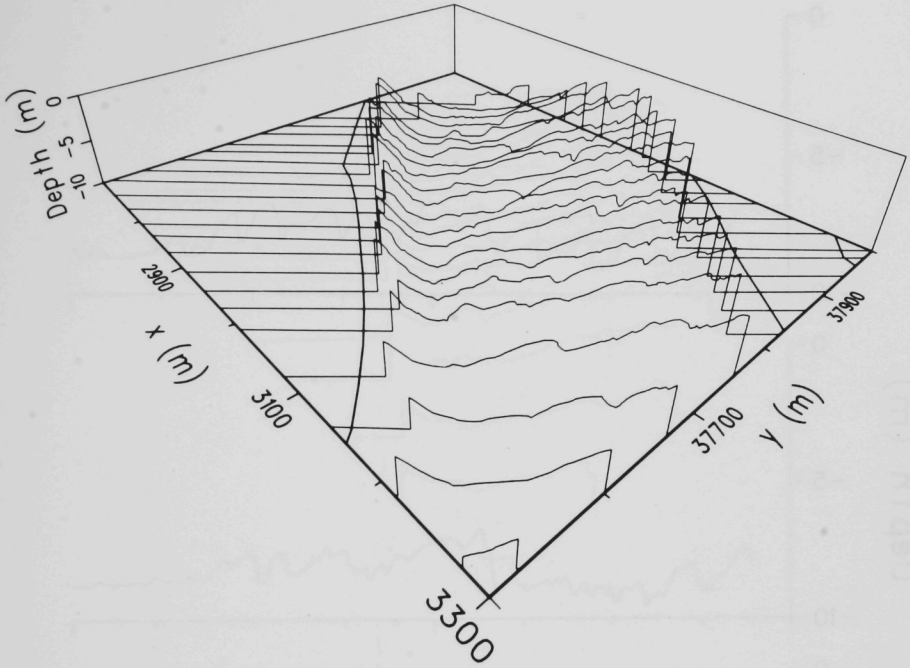

FIGURE 39 Perspective Plot of the Transverse Bathymetric Transects for Survey III at the Duck Creek Disposal Site

4.4 SUMMARY OF DUCK CREEK RESULTS

In October 1983, three dredged sand piles were deposited at the Duck Creek site along the thalweg of the river in a reach that was fairly flat and about 8.5 m deep. The piles were 80-150 m long and 2-3 m high. Bathymetric surveys carried out at intervals during the following nine months showed the following progression. First, small wavelike ripples developed on the tops of the piles. As these ripples grew in amplitude and wavelength, the piles became less and less distinguishable as a topographic feature. Over the winter the ripples developed into dunes with amplitudes and wavelengths comparable to dunes in nearby areas of the river bottom. Following an extended period of flooding from April through July, these dunes had disappeared, and the thalweg had returned to its original flat configuration.

The above sequence of events is depicted in Fig. 45, which shows some of the results from the predisposal survey and each of the five postdisposal surveys. The longitudinal bathymetric transect chosen for Fig. 45 is the one that passes through the disposal area closest to the center of the thalweg. The disposal piles are apparent in

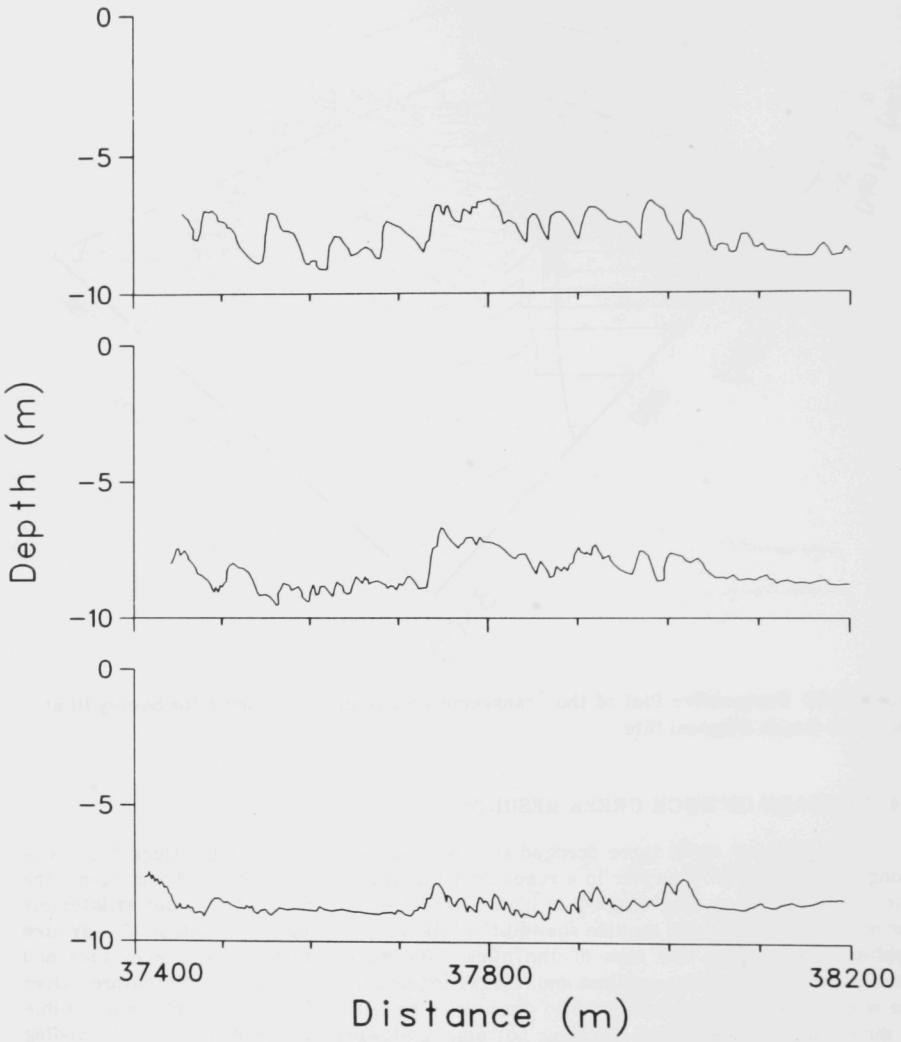

FIGURE 40 Selected Longitudinal Bottom Profiles for Survey III at the Duck Creek Disposal Site

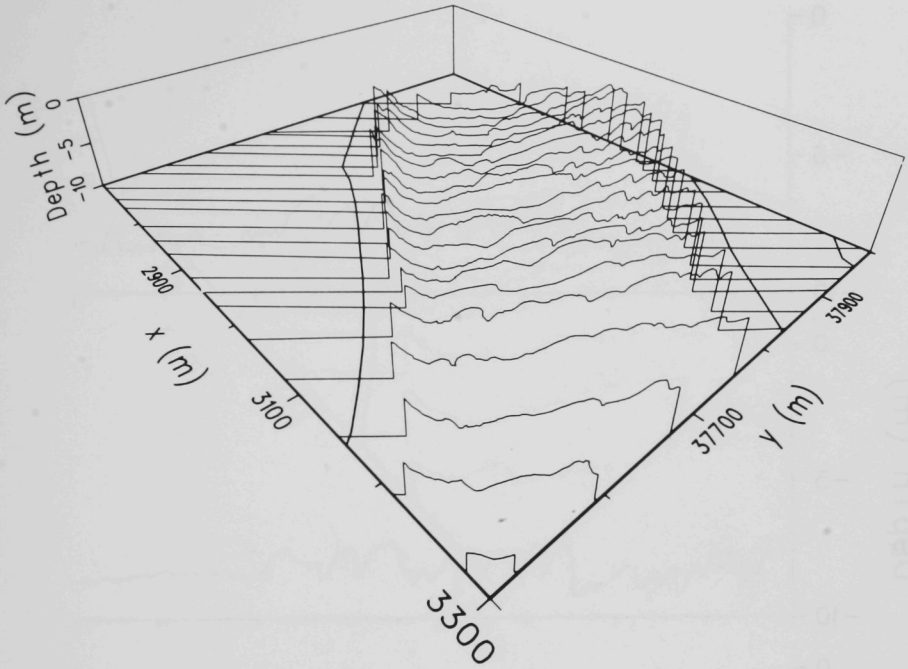

FIGURE 41 Perspective Plot of the Transverse Bathymetric Transects for Survey IV at the Duck Creek Disposal Site

Survey I, as are the small ripples in Survey II. These ripples had grown larger in Survey III and had developed into dunes by Survey IV. By Survey V, after the river hydrograph (see Fig. 29) had essentially completed one annual cycle, the thalweg generally appeared as it did during the predisposal survey.

The flow in the river varies throughout the year but is generally low in late summer and early fall and high in the spring. Additional periods of high or low flow can also occur when the rainfall in the river basin deviates from the normal seasonal pattern. Dredging operations are usually carried out in the late summer and early fall when water levels and flows in the river are low. The next period of relatively high river flow, either during the winter or at least during the following spring runoff, causes the disposal piles to become incorporated into natural features, such as dunes, which move through or develop in the area.

In summary, the disposal piles created in the river thalweg at the Duck Creek site remained as distinct topographic features for only a few months. The same general behavior was observed at the three other sites studied (Gordon's Ferry, Whitney Island, and Savanna Bay).

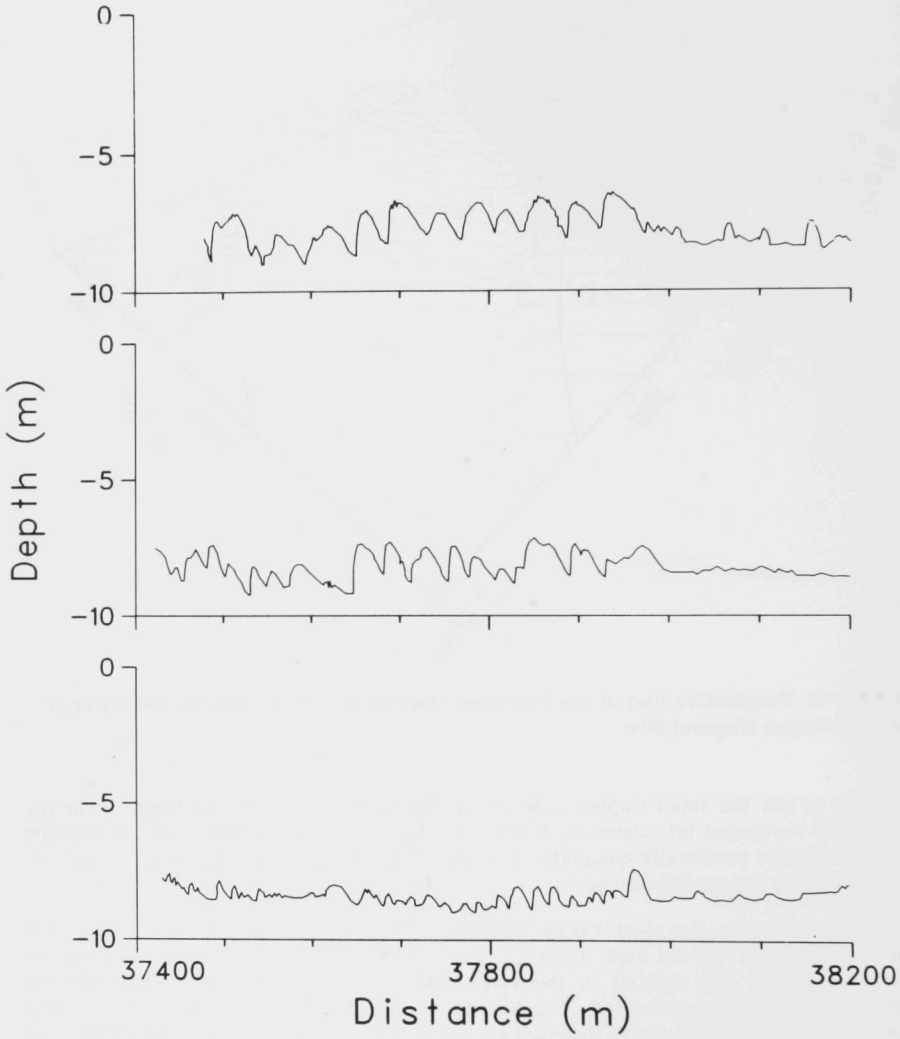

FIGURE 42 Selected Longitudinal Bottom Profiles for Survey IV at the Duck Creek Disposal Site

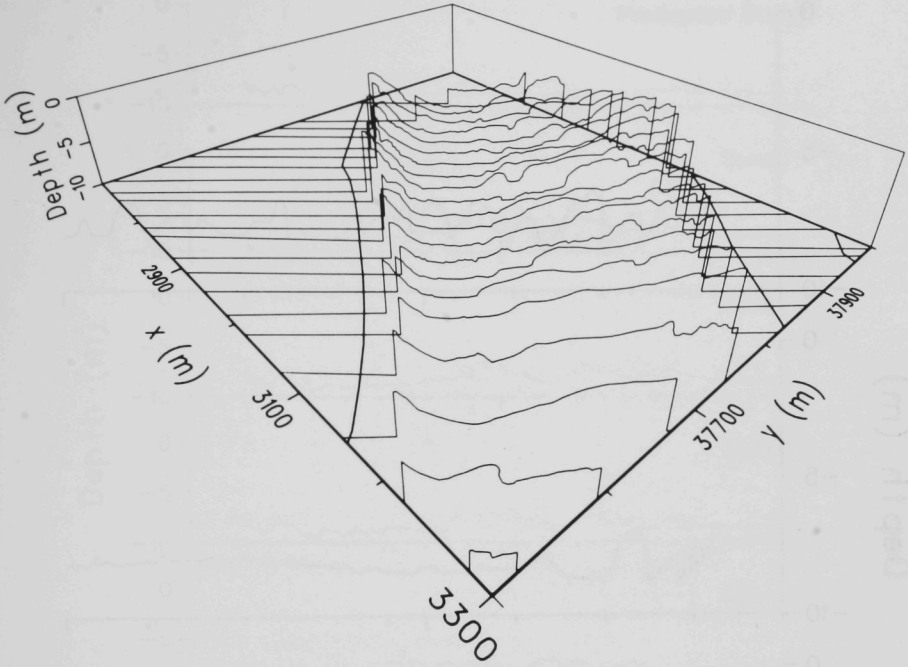

FIGURE 43 Perspective Plot of the Transverse Bathymetric Transects for Survey V at the Duck Creek Disposal Site

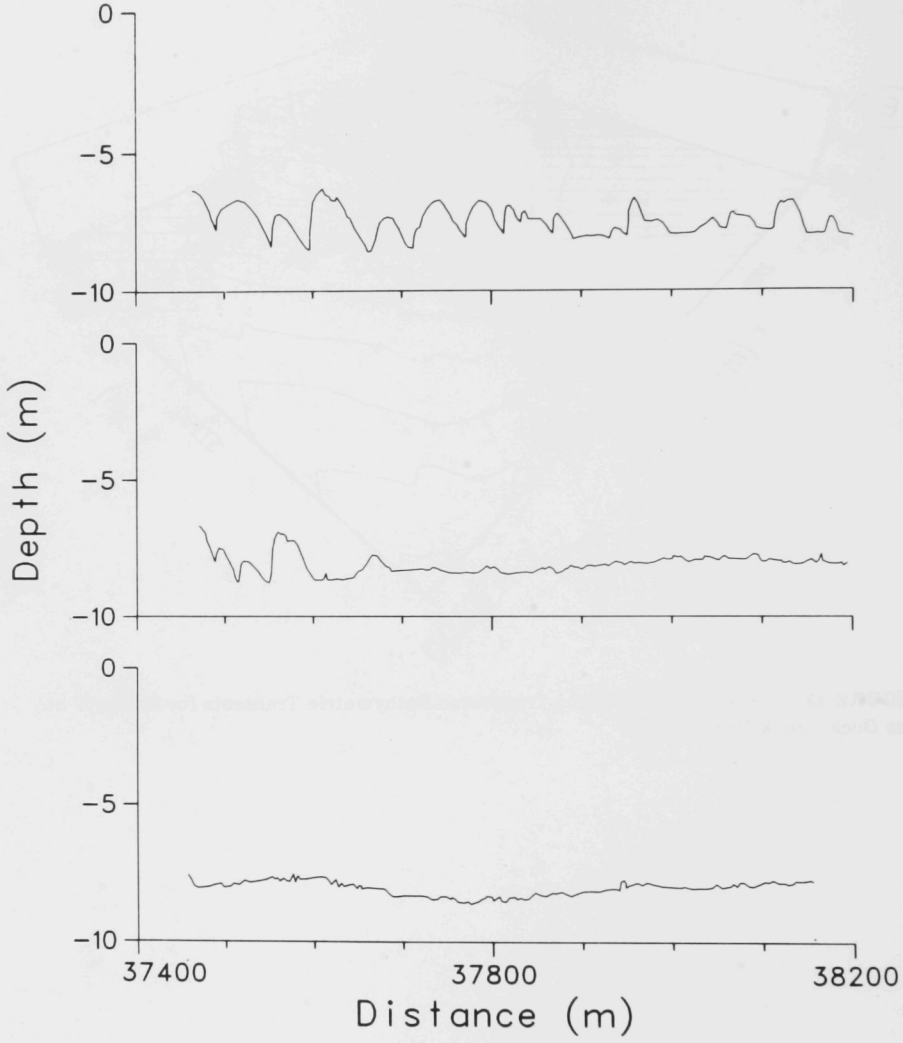

FIGURE 44 Selected Longitudinal Bottom Profiles for Survey V at the Duck Creek Disposal Site

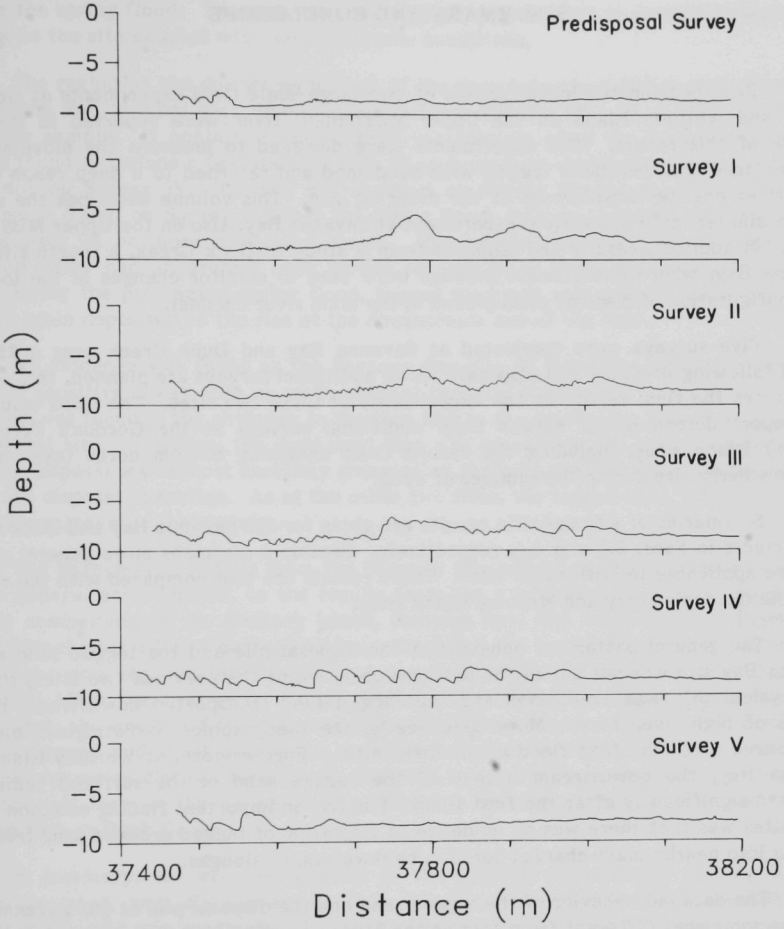

FIGURE 45 Longitudinal Bottom Profile through the Disposal Area for Each of the Bathymetric Surveys at the Duck Creek Site

5 SUMMARY AND CONCLUSIONS

Results from the initial phases of two large-scale field experiments at Gordon's Ferry and Whitney Island on the Upper Mississippi River were reported in the first volume of this report. The experiments were designed to measure the movement of dredged sand that had been tagged with dyed sand and returned to a deep reach of the main river channel downstream of the dredging site. This volume describes the results from a similar large-scale field experiment at Savanna Bay, also on the Upper Mississippi River. In addition, results are reported from a study at Duck Creek, a fourth site near Savanna Bay, where bathymetric surveys were used to monitor changes in the location and configuration of disposal piles placed in the main river channel.

Five surveys were conducted at Savanna Bay and Duck Creek over a 290-day period following dredging and disposal. As no additional surveys are planned, this volume constitutes the final report on the experiments at these two sites. The third volume of this report describes the results from additional surveys at the Gordon's Ferry and Whitney Island sites, including the results from analyzing bottom cores taken at the Gordon's Ferry site during the summer of 1983.

Summaries of site-specific results are given for the Savanna Bay and Duck Creek experiments in Secs. 3.4 and 4.4, respectively. Section 5 discusses more general results that are applicable to both these sites. These results are also compared with the results from the Gordon's Ferry and Whitney Island sites.

The general pattern of behavior of the disposal pile and the tagged sand at the Savanna Bay site was not unlike the patterns observed at the previous two sites; that is, the physical pile was eradicated and the tagged sand transported downstream during periods of high river flow. More specifically, the topographically distinguishable pile disappeared after the first flood at all three sites. Furthermore, at Whitney Island and Savanna Bay, the downstream extent of the tagged sand in the surficial sediments increased significantly after the first flood. Finally, an important finding common to all three sites was that there was no evidence of migration of tagged dredged sand from the thalweg into nearby main-channel borders, backwaters, or sloughs.

The detailed behavior of the tagged sand and the disposal pile at the Savanna Bay site was somewhat different from that at the other two sites; however, these differences can be attributed to differences in site topography and local flow conditions. The tagged sand at Savanna Bay, as delineated by the three-dyed-sand-grain contour, covered a much larger area and extended much farther downstream immediately after disposal than at either Gordon's Ferry or Whitney Island. Because of the large areal extent of the three-dyed-sand-grain contour at Savanna Bay, the thirty-dyed-sand-grain contour was used to identify the location of the bulk of the tagged sand in the immediate disposal area.

The initial area of the thirty-dyed-sand-grain contour at Savanna Bay was approximately equivalent to the initial areas of the three-dyed-sand-grain contours at the other two sites, while the downstream extent and the areal extent of the three-dyed-sand-grain contour at Savanna Bay did not change until after the spring flood. The thirty-dyed-sand-grain contour did exhibit some survey-to-survey changes in position

prior to the spring flood. These changes were apparently related to specific topographic features at the site coupled with local hydraulic conditions.

The region on the downstream slope of the deep hole about 800 m downstream of the Savanna Bay disposal area often yielded bottom samples with 30 or more dyed sand grains per sample. It contained tagged sand immediately after the dredging operation and was found to include a few stations with 30 or more dyed sand grains on Surveys I and II but not on Survey IV. (It was not sampled on Survey III due to difficult winter conditions.) Then, on Survey V, after the spring flood, that region again included a few stations with 30 or more dyed sand grains. The tagged sand that had initially been deposited there had apparently been slowly scoured away until, by Survey IV, it was gone. During the protracted spring flood, tagged sand was transported across the deep hole and again deposited on the rise at the downstream end of the hole.

No evidence was found at the Savanna Bay site of migration of tagged dredged sand into sensitive areas such as main-channel borders, sloughs, or backwaters. Some dyed sand was found in the entrance to Savanna Bay to the east of the islands adjacent to the disposal site. However, the dyed sand that was present on the survey immediately following disposal was almost certainly transported there by the flow between the islands during the disposal operation. As at the other two sites, the tagged sand, when it moved, moved downstream in the thalweg.

The bathymetric results from the Savanna Bay and Duck Creek sites are similar, both in general and in detail, to the results from the experiment at Whitney Island. A detailed comparison of the Whitney Island, Savanna Bay, and Duck Creek bathymetric results with Gordon's Ferry bathymetric results during the period prior to the first major flood is not possible because longitudinal transects were not established at Gordon's Ferry until after the first major flood. During the period from disposal until the first major flood, the height of the disposal piles at Whitney Island, Savanna Bay, and Duck Creek decreased and small waveforms developed on the piles. Following the flood, the piles disappeared as distinct topographic features, and the bottom essentially returned to its predisposal form -- dune structures at Whitney Island and Savanna Bay, and a flat, rocky bottom at Duck Creek.

In summary, the general behavior of the physical disposal pile and the tagged sand, when used, was similar at all four experimental sites. The topographically distinguishable pile was eradicated during the first major flood, and the tagged sand was transported downstream in the thalweg during periods of high flow. Although differences were apparent in the detailed results from each of the sites, they can reasonably be attributed to the particular configuration of the original disposal pile, the local site hydraulics, and the predisposal bottom topography.

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2. Nanda, S.K., and R.M. Baker, *Experience in Channel Maintenance in Upper Mississippi River*, in River Meandering, Proc. Rivers '83 Conf., C.M. Elliott, ed., American Society of Civil Engineers, New York, pp. 471-482 (1984).

3. Lagasse, P.F., et al., *Thalweg Disposal of Riverine Dredged Material*, Proc. Specialty Conf. on Dredging and Its Environmental Effects, sponsored by American Society of Civil Engineers, New York, pp. 556-576 (1976).

4. *Main Report, GREAT II: Upper Mississippi River (Guttenberg, Iowa, to Saverton, Missouri)*, Great River Environmental Action Team, U.S. Army Corps of Engineers, Rock Island District, Rock Island, Ill. (Dec. 1980).

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APPENDIX A

SAVANNA BAY — DETAILED DATA

APPENDIX A

SAVANNA BAY — DETAILED DATA

Results of the six surveys at the Savanna Bay site, along with some of the supporting data, were presented in Sec. 3. The complete sets of bathymetric data and dyed sand data from each of these surveys are given in Secs. A.1 and A.2 of this appendix.

A.1 BATHYMETRIC DATA FROM THE SAVANNA BAY DISPOSAL SITE

The complete bathymetric data from the predisposal survey and the five postdisposal surveys at Savanna Bay are presented in Figs. A.1-A.11. The approximate boat paths for each survey are shown in the upper left-hand quadrant. The bottom profiles for the transverse transects are then presented in sequence, starting in the upper right-hand quadrant with the transect farthest upstream and proceeding downstream. The profiles for the individual transects start from the Iowa (west) end. The bottom profiles for the longitudinal transects, which are approximately parallel to the original disposal pile, are then presented in sequence, starting with the transect closest to the Illinois (east) shore and proceeding toward the Iowa (west) shore. The profiles for the individual transects start from the downstream end of each transect.

A.2 DYED SAND DATA FROM THE SAVANNA BAY DISPOSAL SITE

The locations of the bottom-sampling stations for each of the five postdisposal surveys at Savanna Bay are given in Sec. A.2. For presentation purposes, the study area was divided into four regions (a, b, c, and d) as shown in Fig. A.12. Region a encompasses the original disposal area and the downstream entrance to Savanna Bay. The other three regions cover successive downstream main-channel and border areas. The sampling locations for Surveys I-V are shown in Figs. A.13-A.32. The number of individual dyed sand grains, if any, observed in the photographs of the surface of the 23 × 23 cm sample tray illuminated by ultraviolet light is given adjacent to each sampling location.

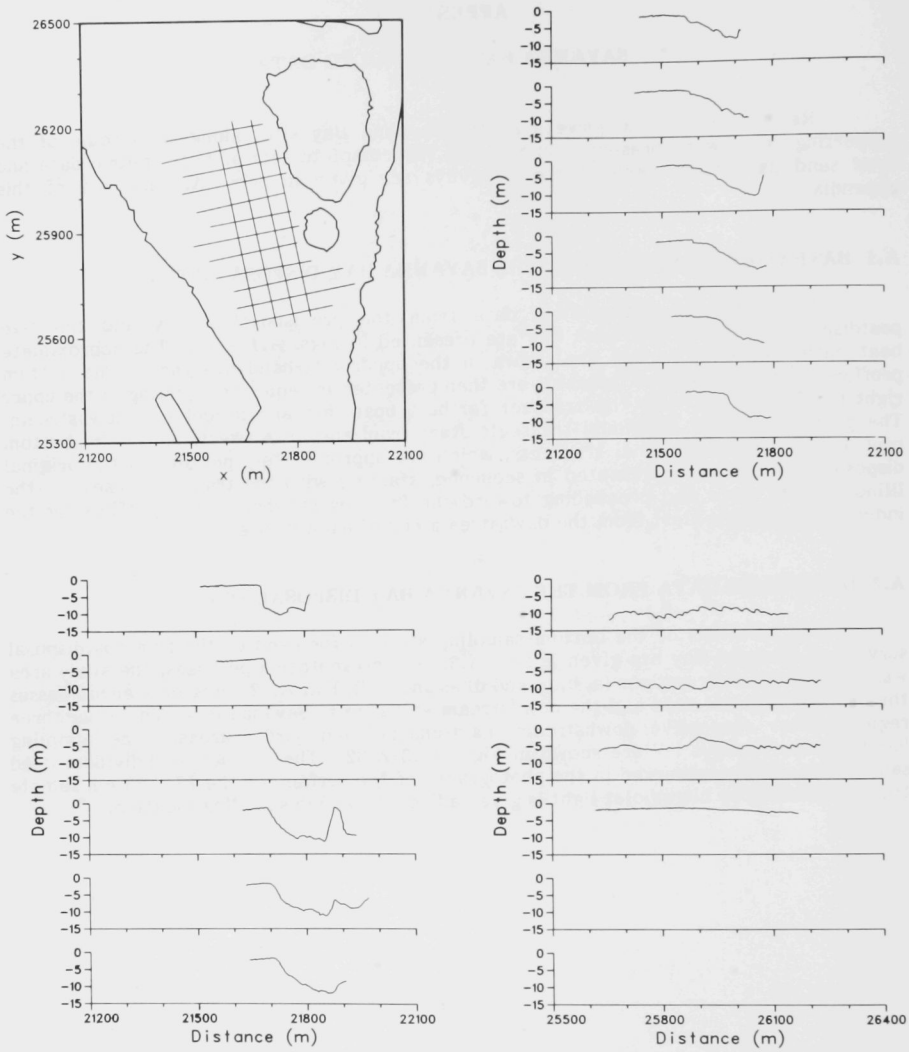

FIGURE A.1 Bathymetric Transects and Transverse and Longitudinal Bottom Profiles for the Predisposal Survey at Savanna Bay on October 24, 1983

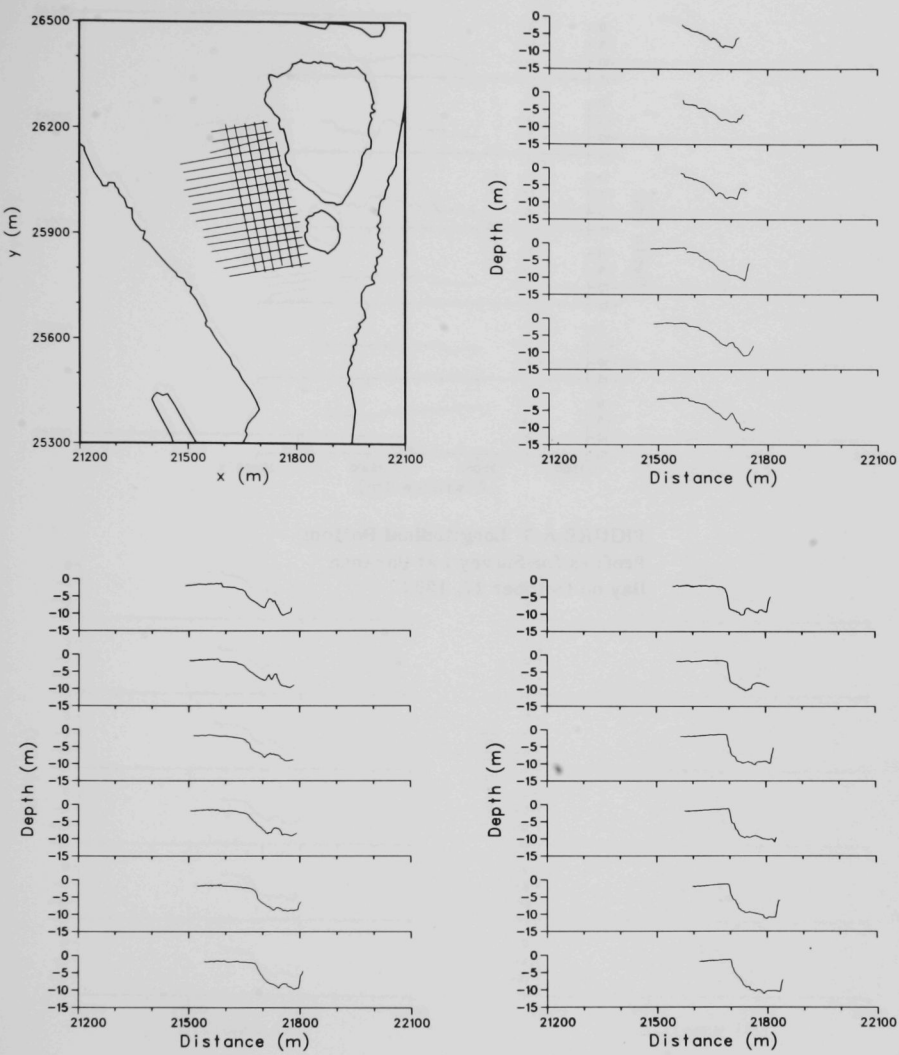

FIGURE A.2 Bathymetric Transects and Transverse Bottom Profiles for Survey I at Savanna Bay on October 27, 1983

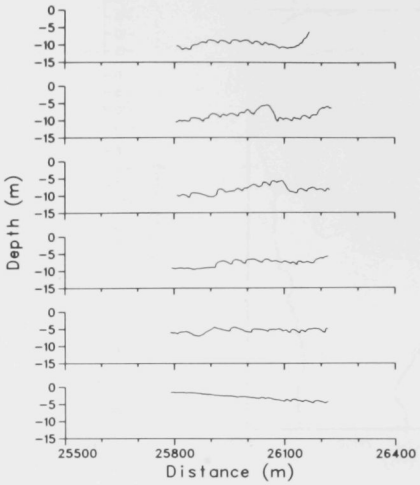

FIGURE A.3 Longitudinal Bottom Profiles for Survey I at Savanna Bay on October 27, 1983

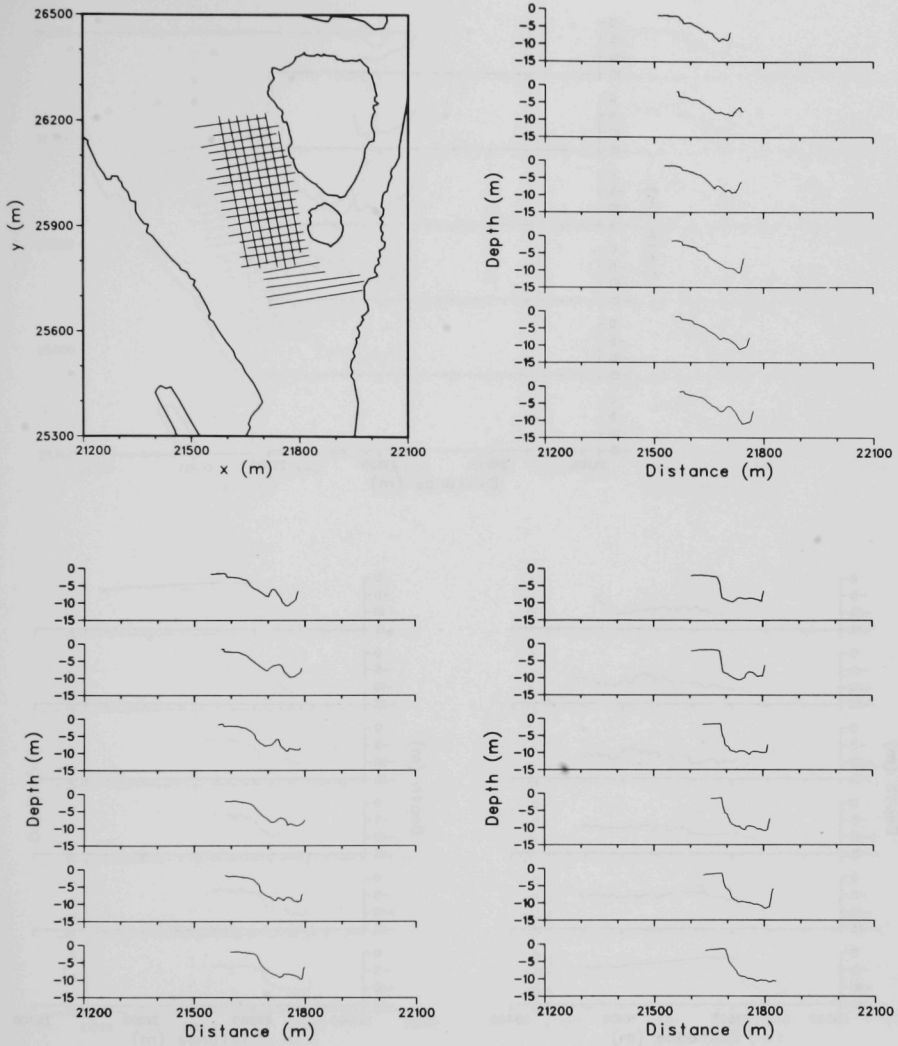

FIGURE A.4 Bathymetric Transects and Transverse Bottom Profiles for Survey II at Savanna Bay on November 7, 1983

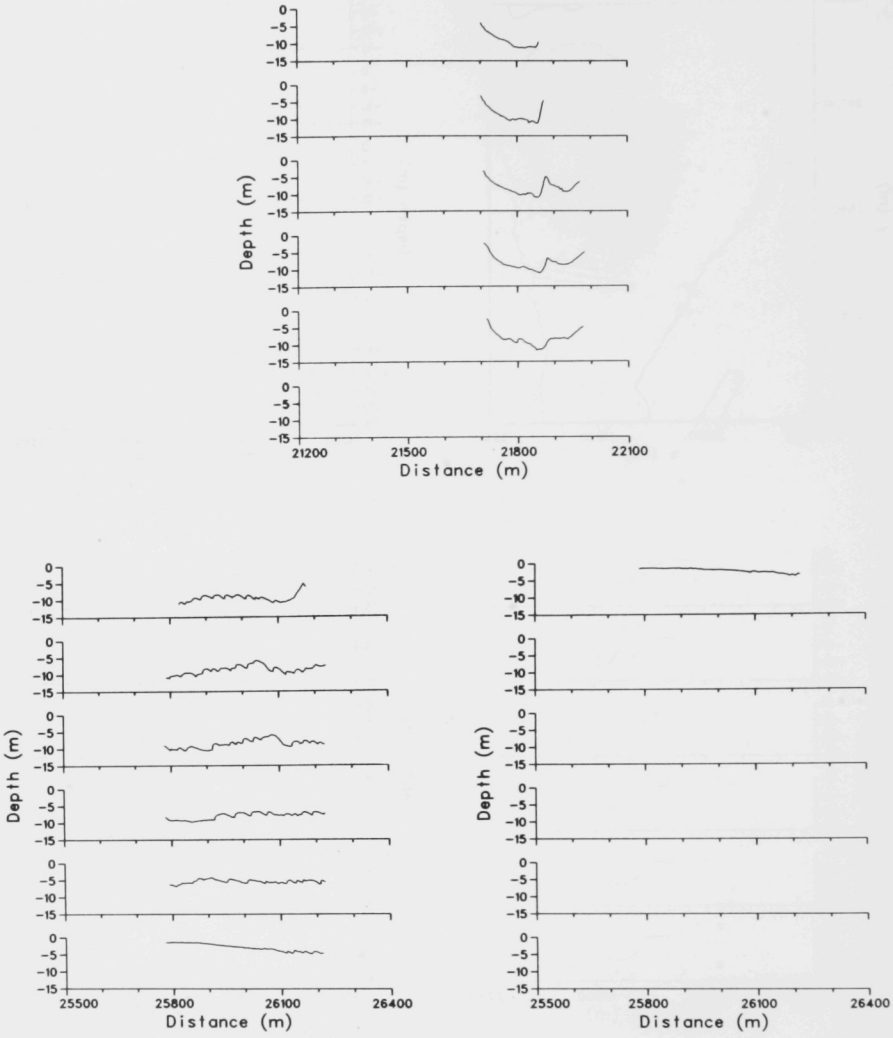

FIGURE A.5 Transverse and Longitudinal Bottom Profiles for Survey II at Savanna Bay on November 7, 1983

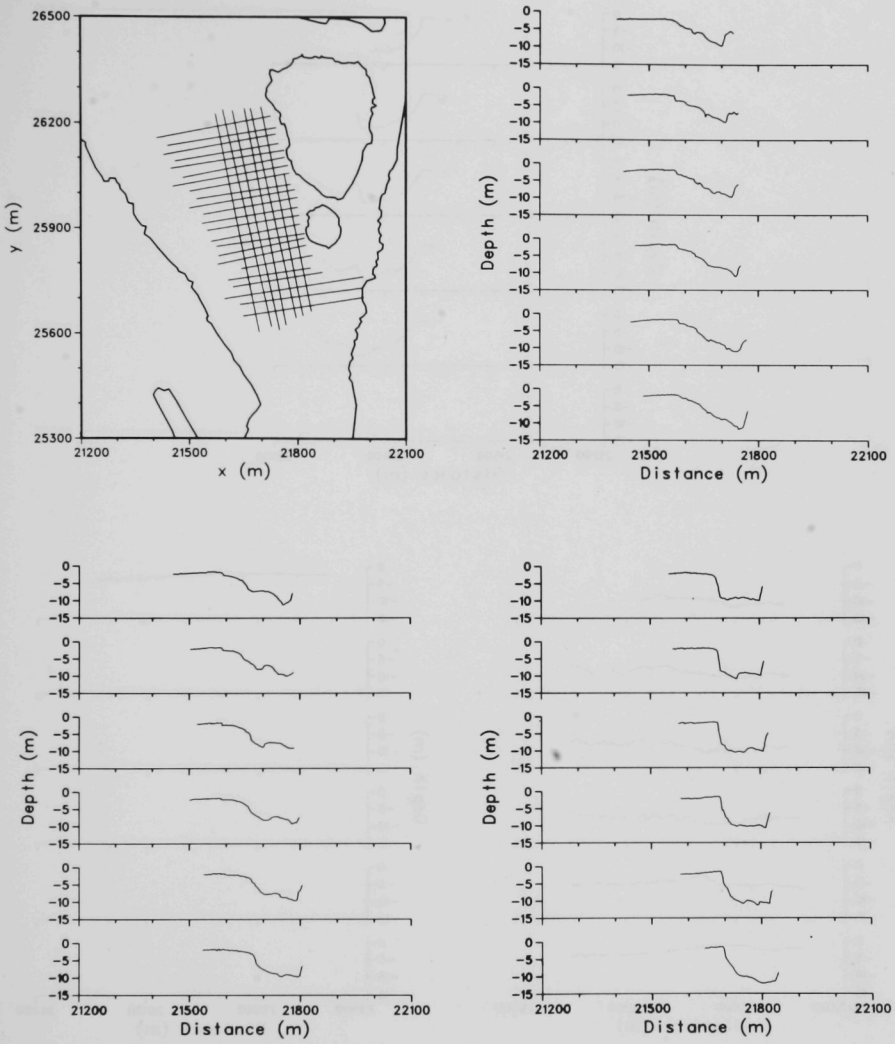

FIGURE A.6 Bathymetric Transects and Transverse Bottom Profiles for Survey III at Savanna Bay on December 13, 1983

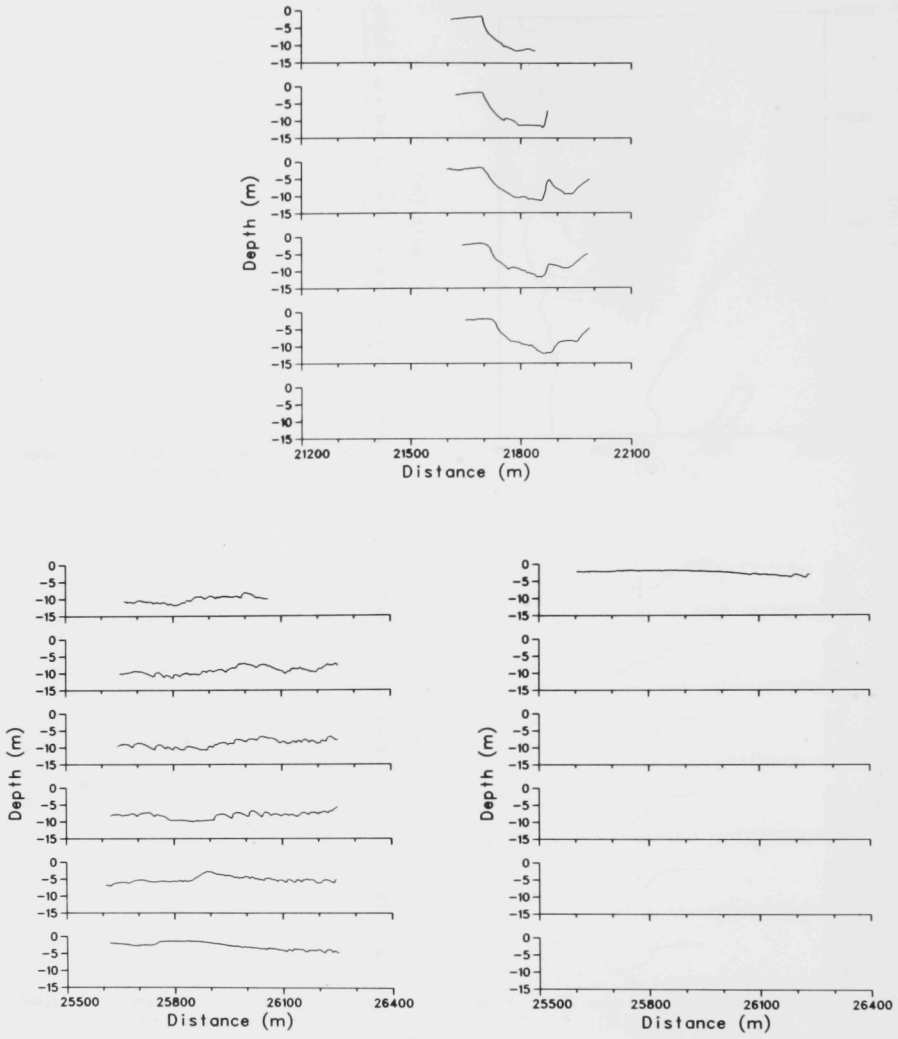

FIGURE A.7 Transverse and Longitudinal Bottom Profiles for Survey III at Savanna Bay on December 13, 1983

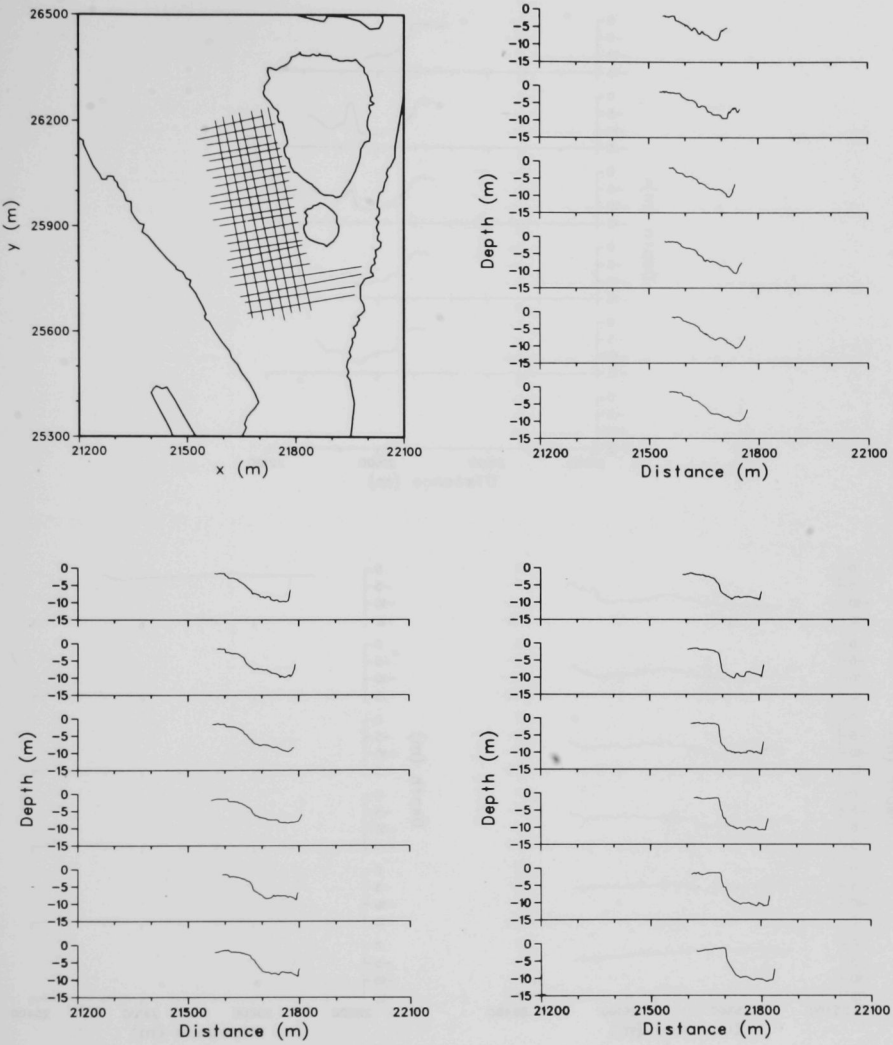

FIGURE A.8 Bathymetric Transects and Transverse Bottom Profiles for Survey IV at Savanna Bay on March 28, 1984

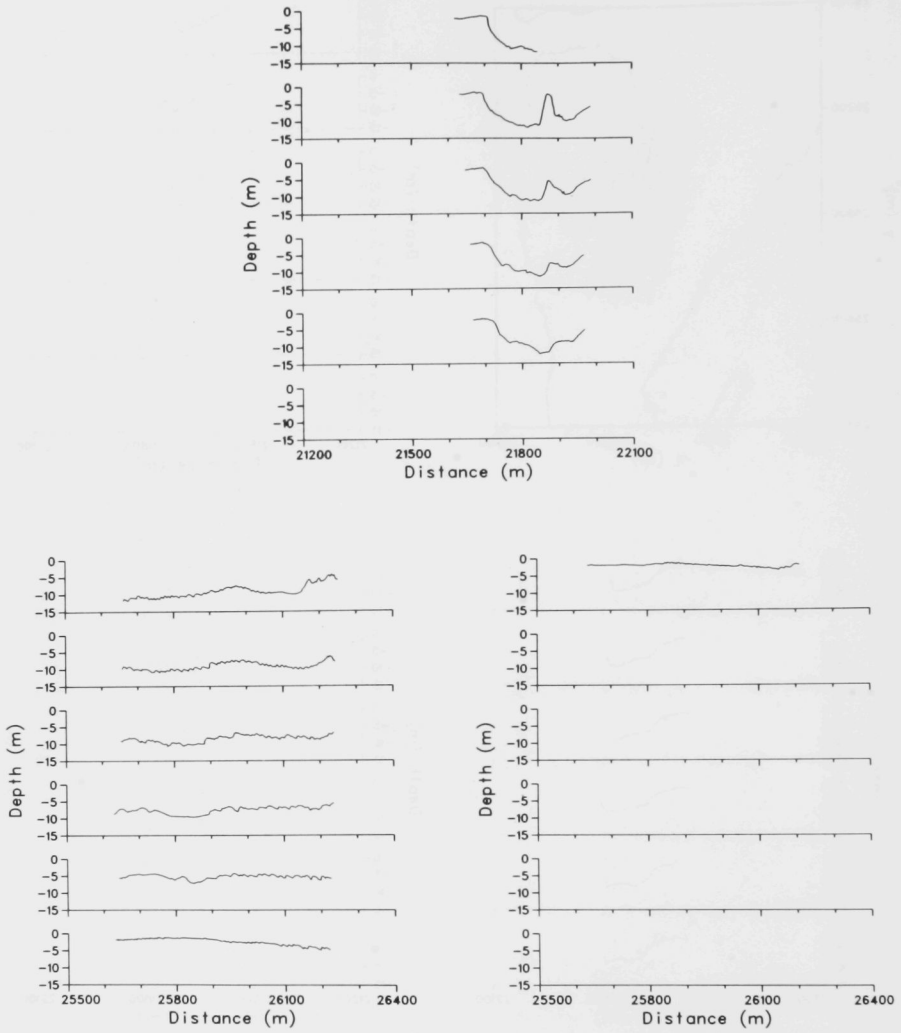

FIGURE A.9 Transverse and Longitudinal Bottom Profiles for Survey IV at Savanna Bay on March 28, 1984

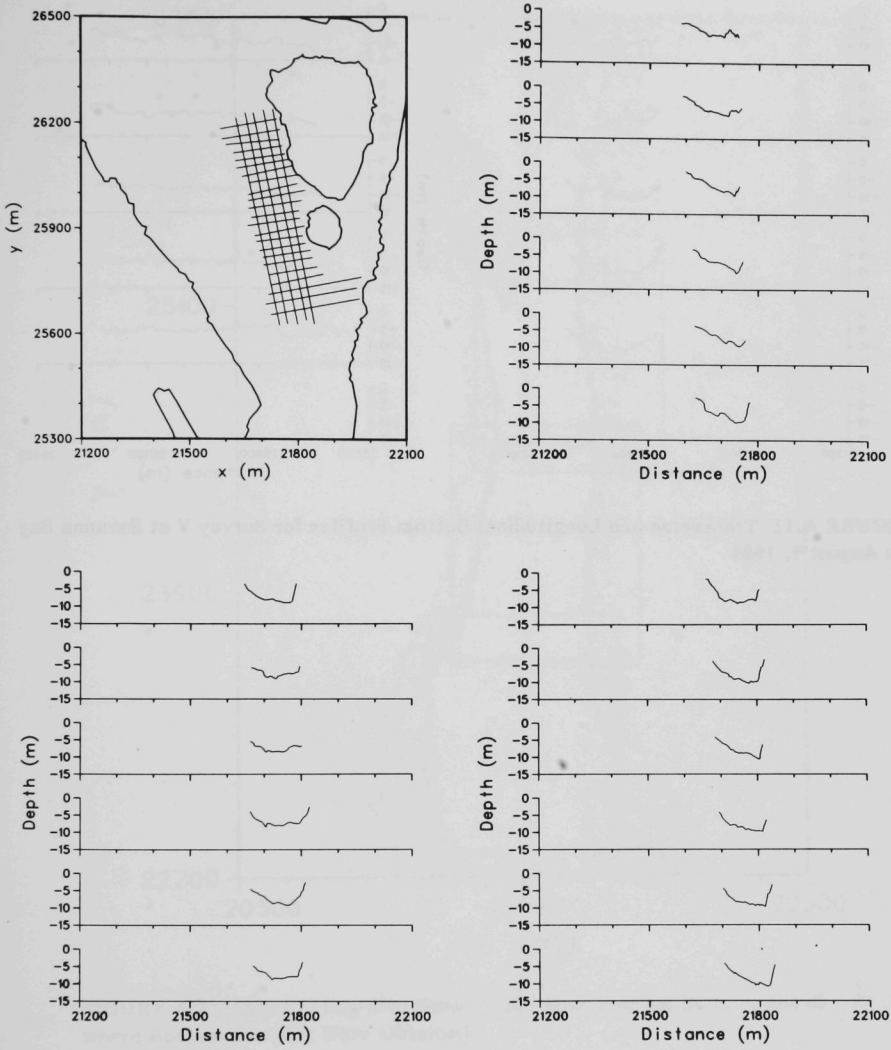

FIGURE A.10 Bathymetric Transects and Transverse Bottom Profiles for Survey V at Savanna Bay on August 1, 1984

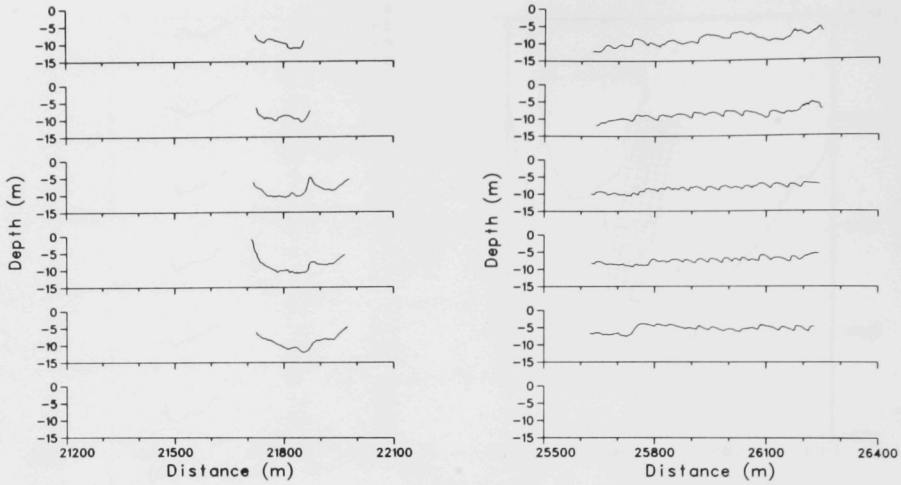

FIGURE A.11 Transverse and Longitudinal Bottom Profiles for Survey V at Savanna Bay on August 1, 1984

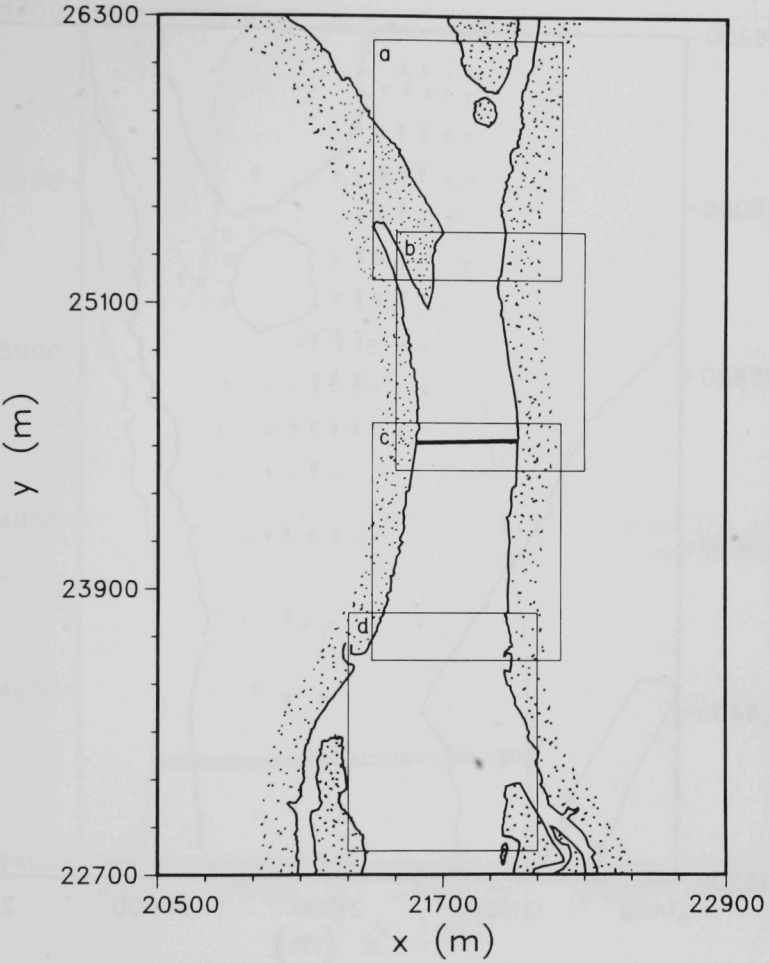

FIGURE A.12 Savanna Bay Site Showing the Four Regions (a, b, c, and d) where Bottom Samples Were Obtained

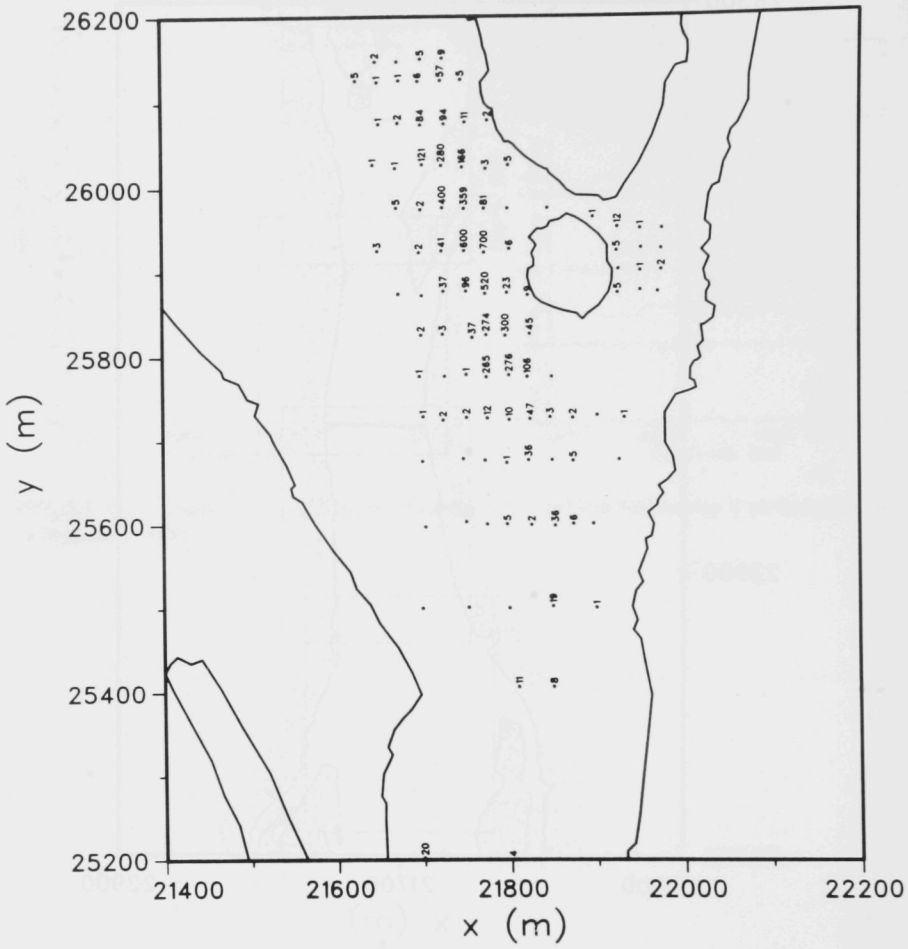

FIGURE A.13 Bottom Sampling Locations and Dyed Sand Counts in Region a of the Savanna Bay Site for Survey I

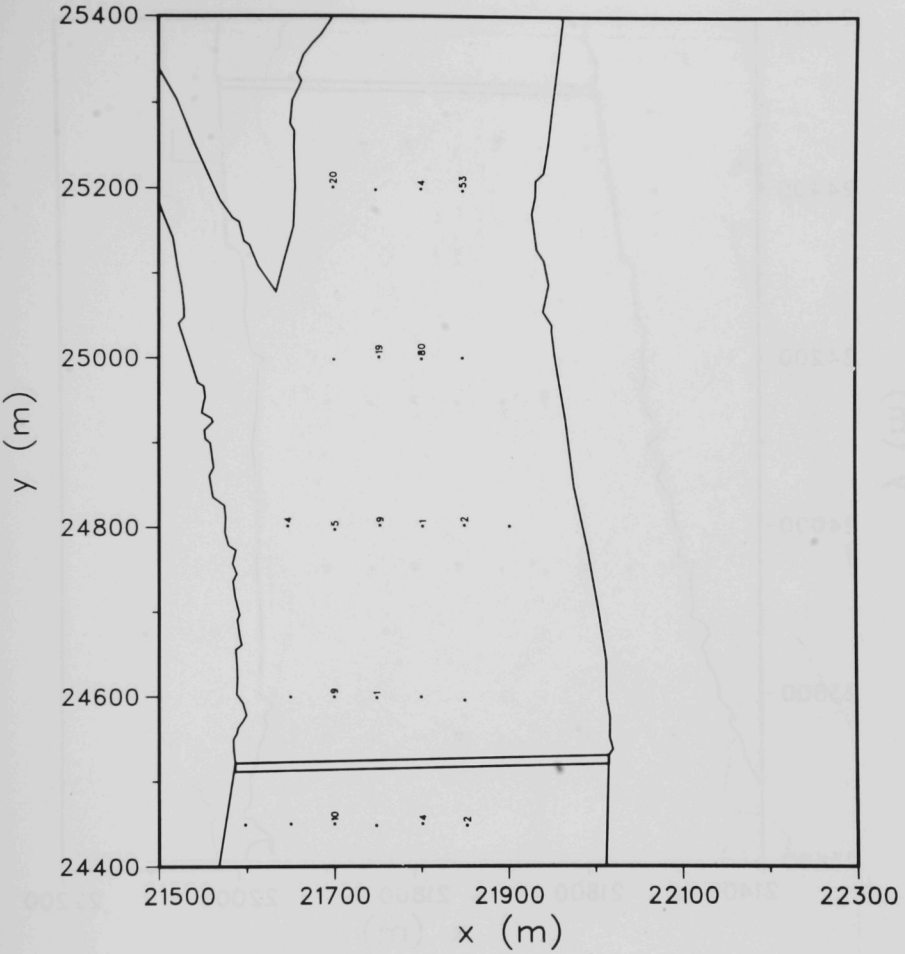

FIGURE A.14 Bottom Sampling Locations and Dyed Sand Counts in Region b of the Savanna Bay Site for Survey I

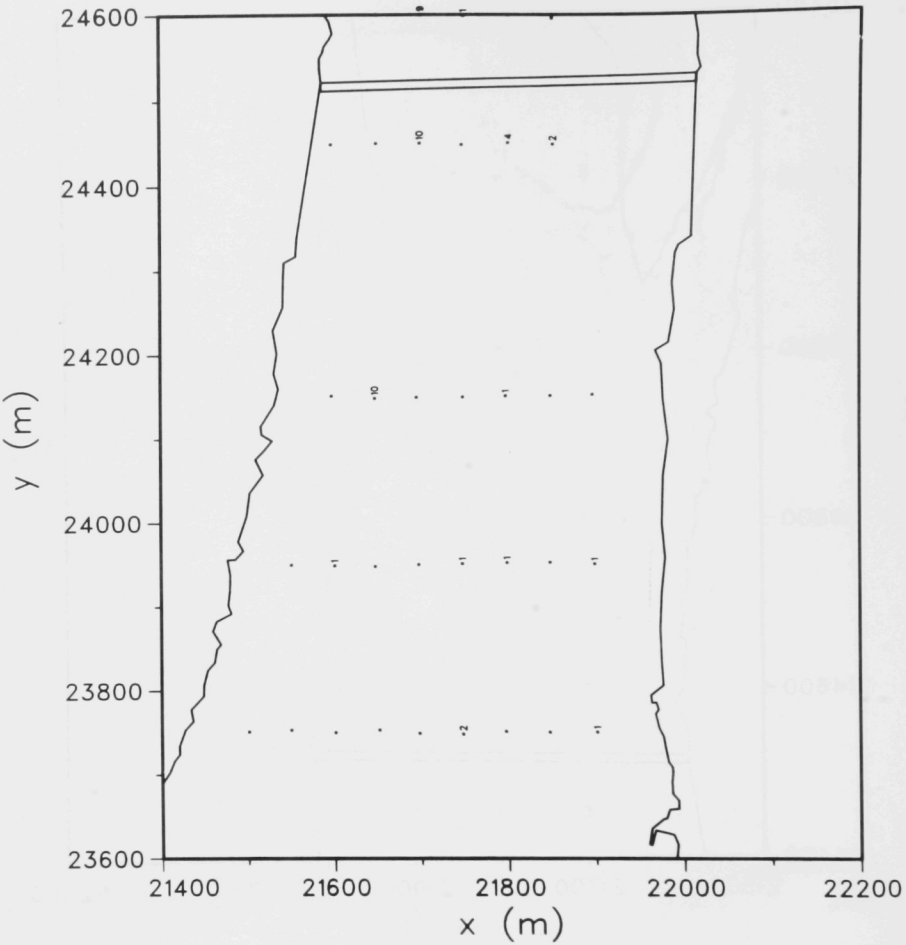

FIGURE A.15 Bottom Sampling Locations and Dyed Sand Counts in Region c of the Savanna Bay Site for Survey I

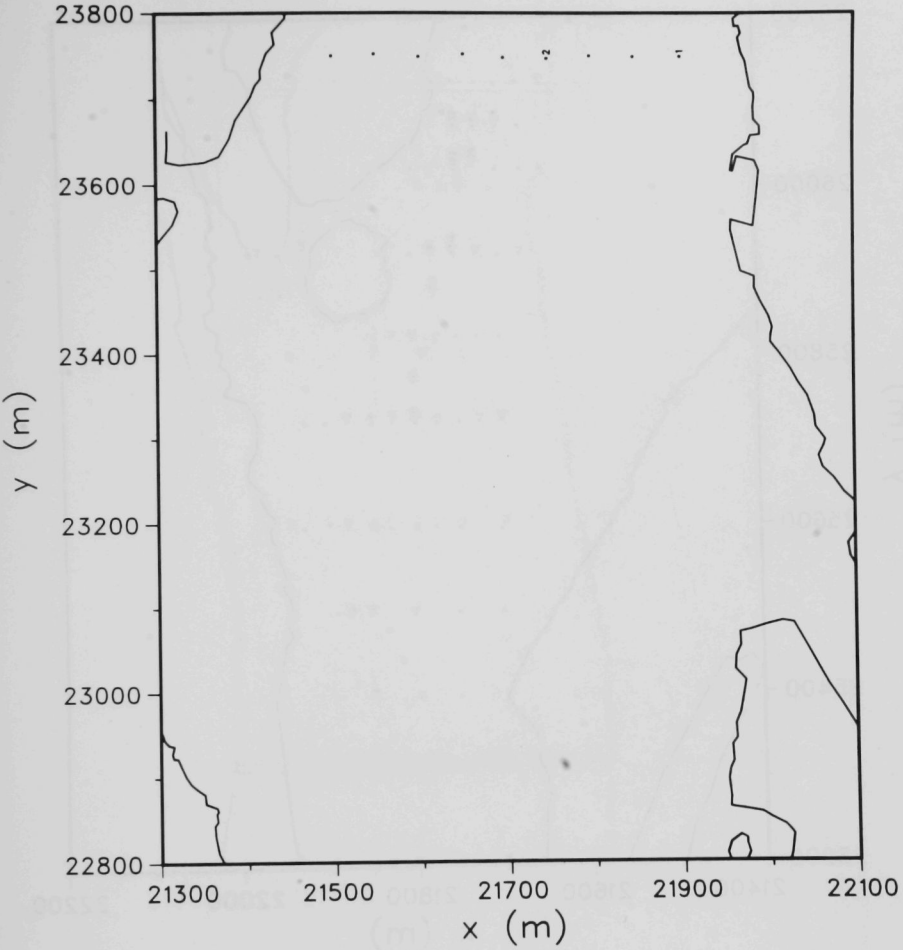

FIGURE A.16 Bottom Sampling Locations and Dyed Sand Counts in Region d of the Savanna Bay site for Survey I

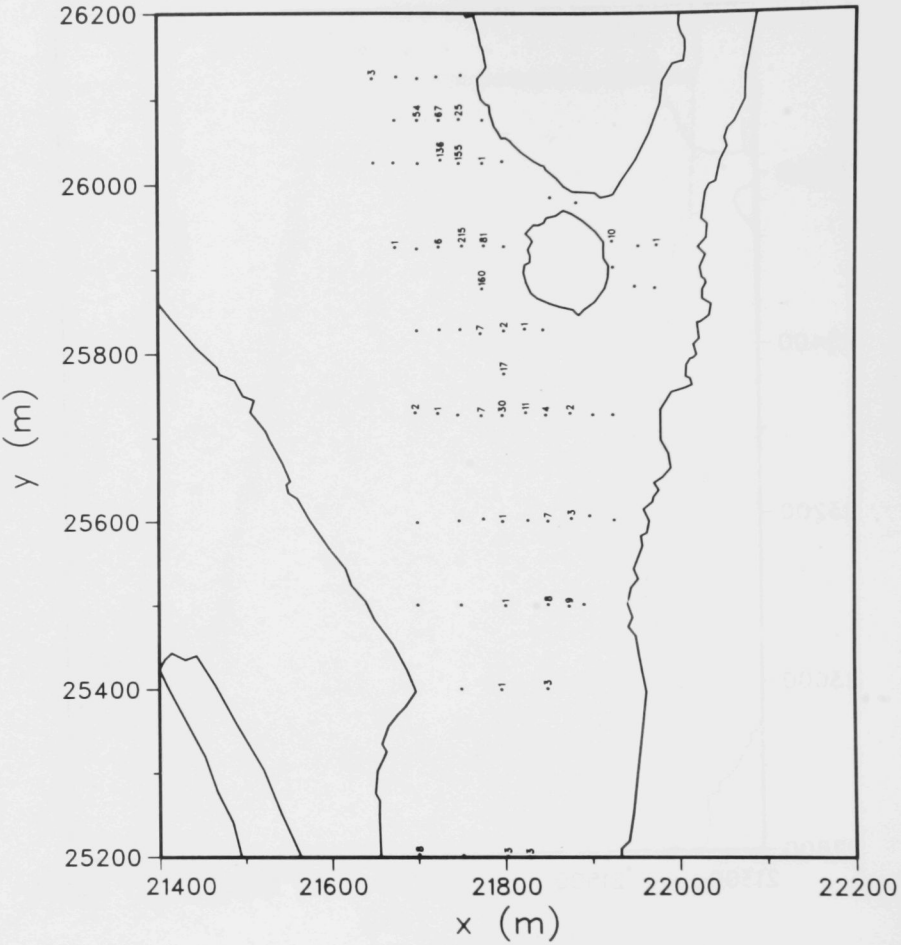

FIGURE A.17 Bottom Sampling Locations and Dyed Sand Counts in Region a of the Savanna Bay Site for Survey II

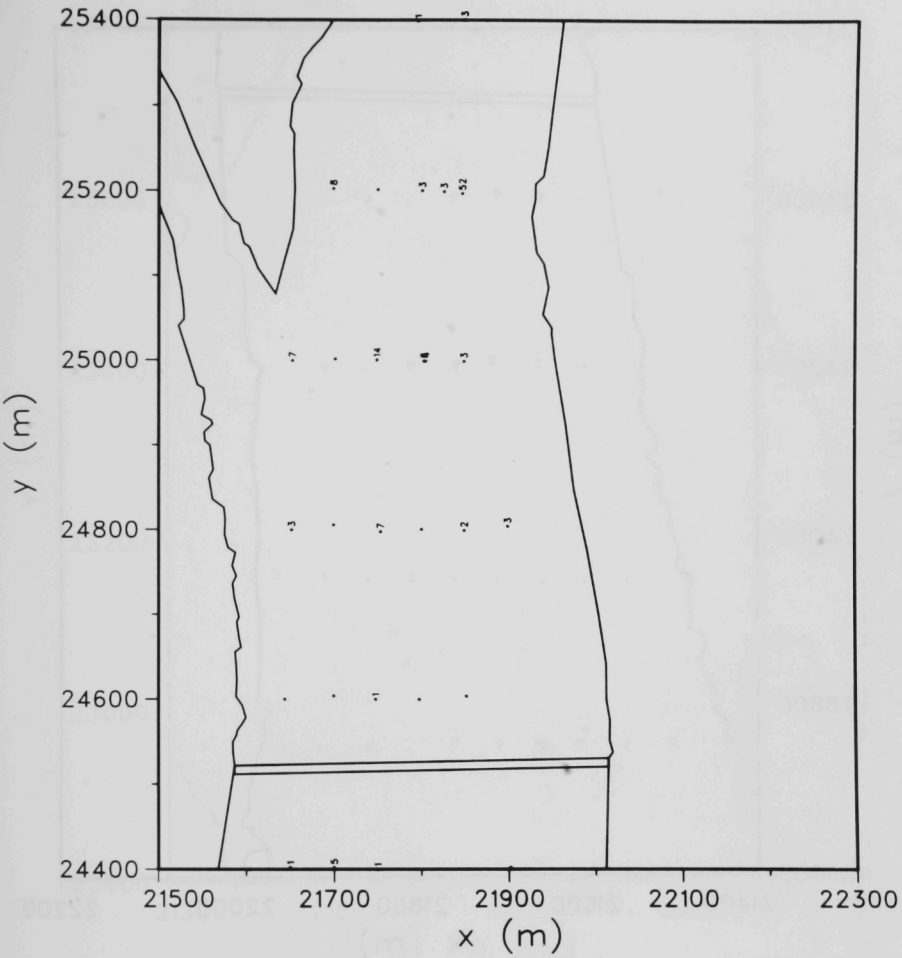

FIGURE A.18 Bottom Sampling Locations and Dyed Sand Counts in Region b of the Savanna Bay Site for Survey II

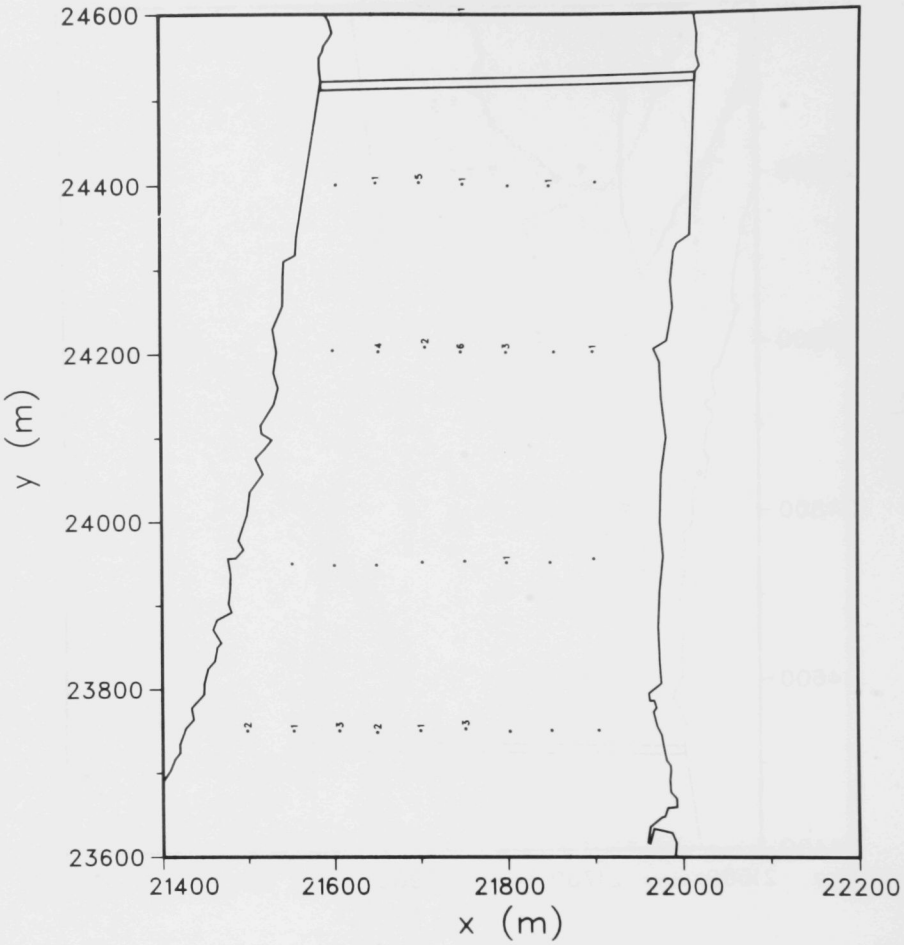

FIGURE A.19 Bottom Sampling Locations and Dyed Sand Counts in Region c of the Savanna Bay Site for Survey II

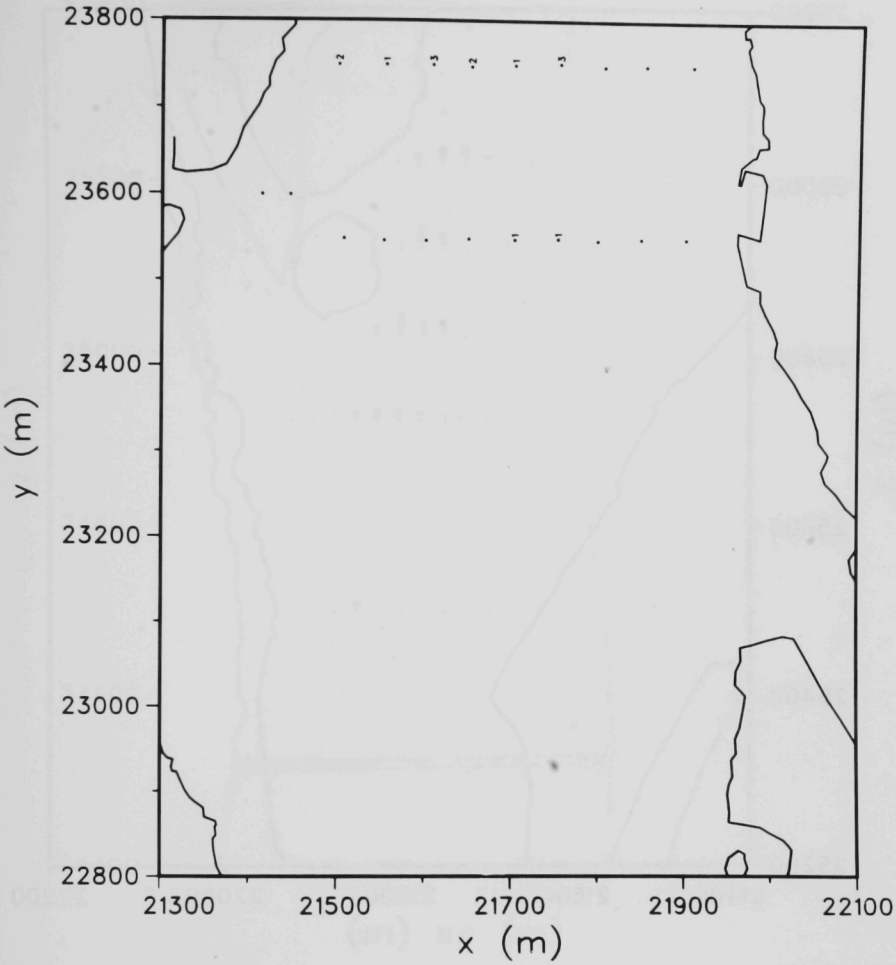

FIGURE A.20 Bottom Sampling Locations and Dyed Sand Counts in Region d of the Savanna Bay Site for Survey II

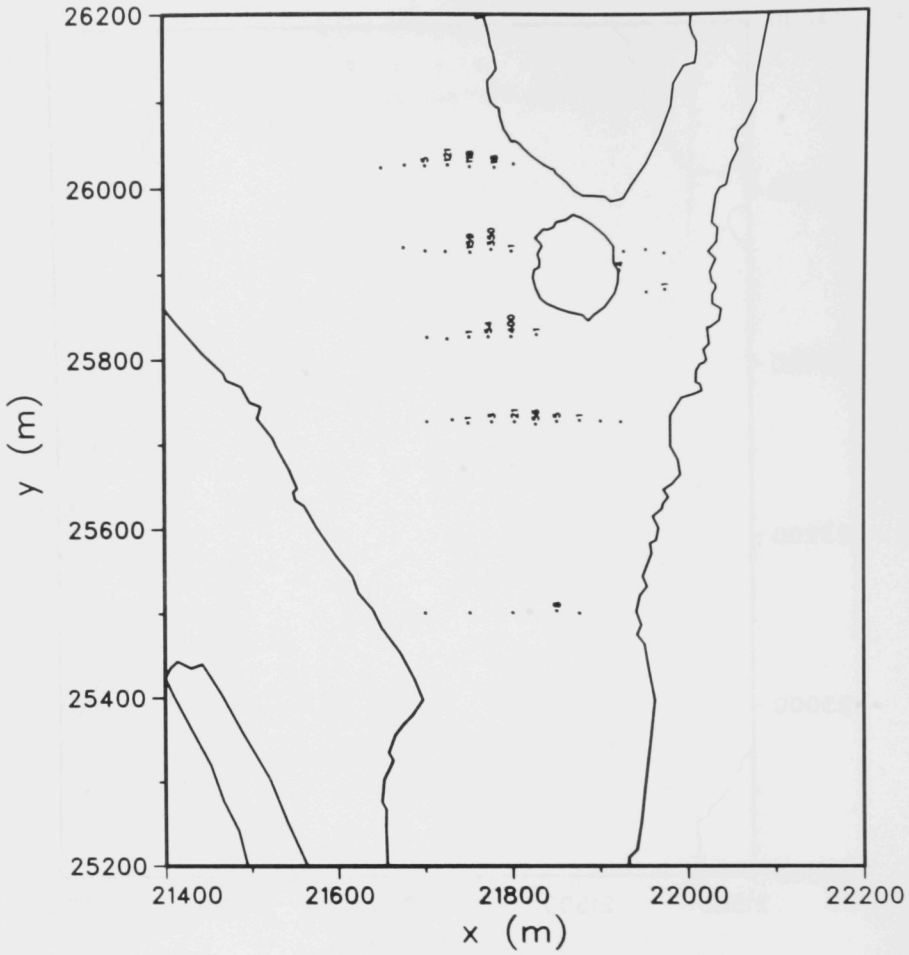

FIGURE A.21 Bottom Sampling Locations and Dyed Sand Counts in Region a of the Savanna Bay Site for Survey III

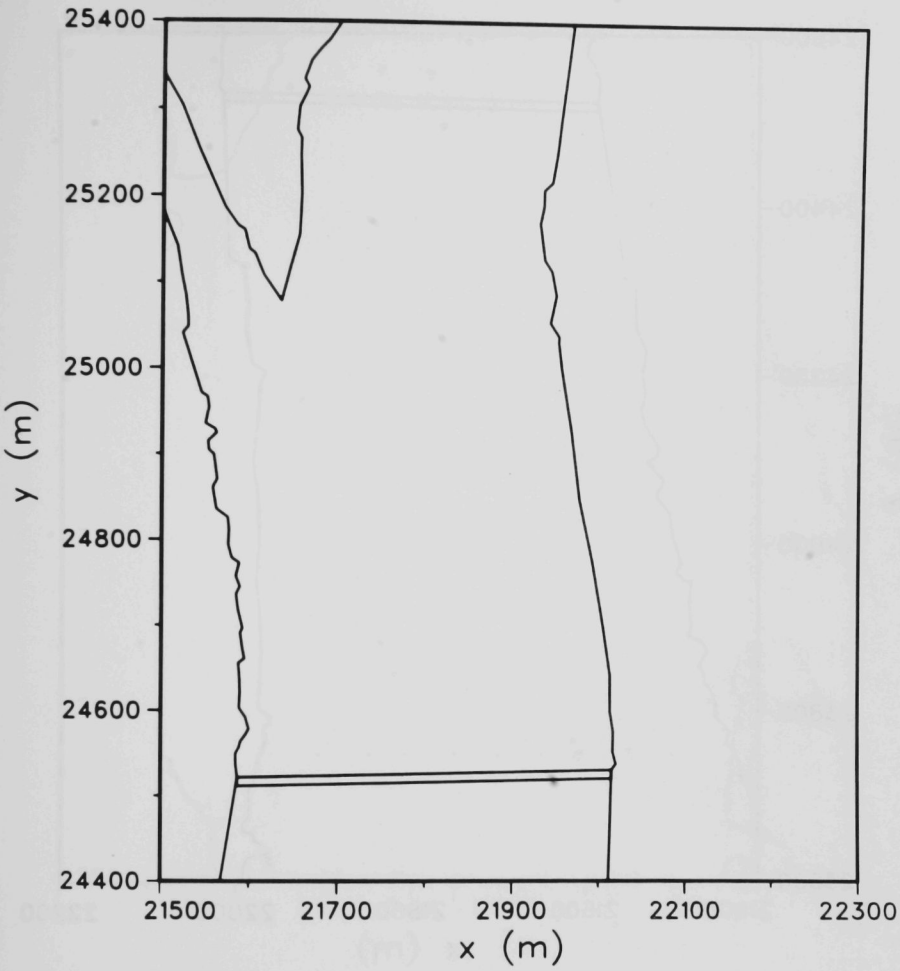

FIGURE A.22 Bottom Sampling Locations and Dyed Sand Counts in Region b of the Savanna Bay Site for Survey III

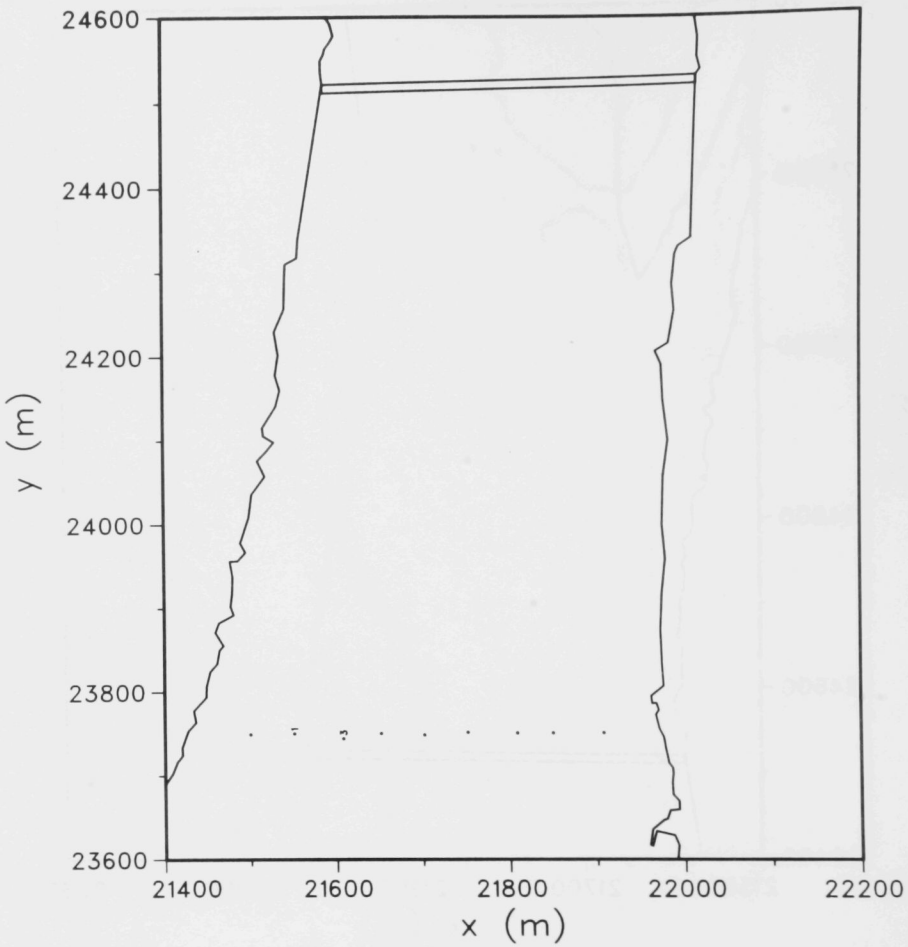

FIGURE A.23 Bottom Sampling Locations and Dyed Sand Counts in Region c of the Savanna Bay Site for Survey III

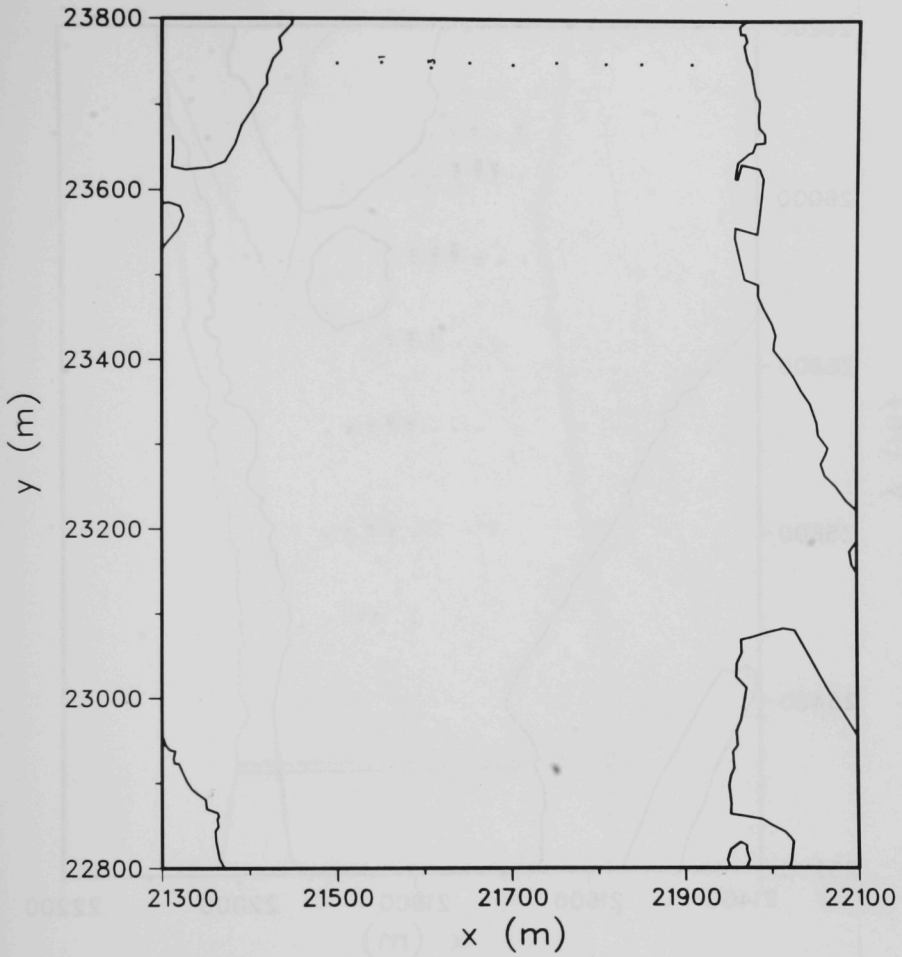

FIGURE A.24 Bottom Sampling Locations and Dyed Sand Counts in Region d of the Savanna Bay Site for Survey III

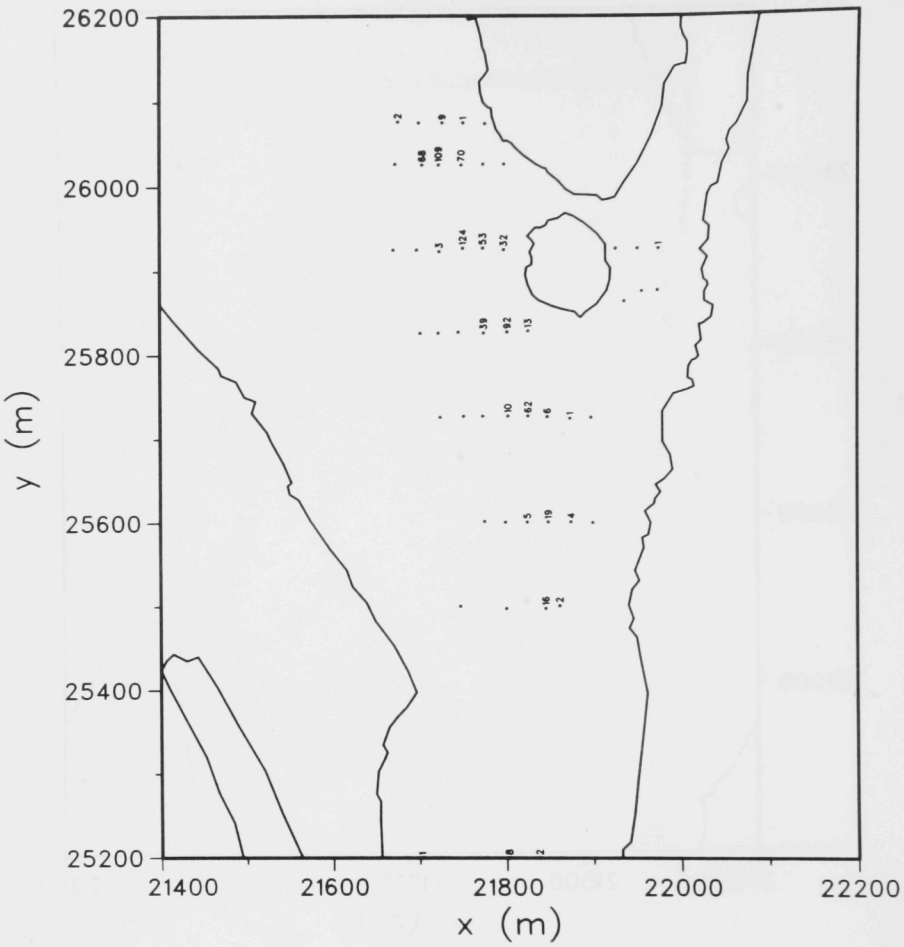

FIGURE A.25 Bottom Sampling Locations and Dyed Sand Counts in Region a of the Savanna Bay Site for Survey IV

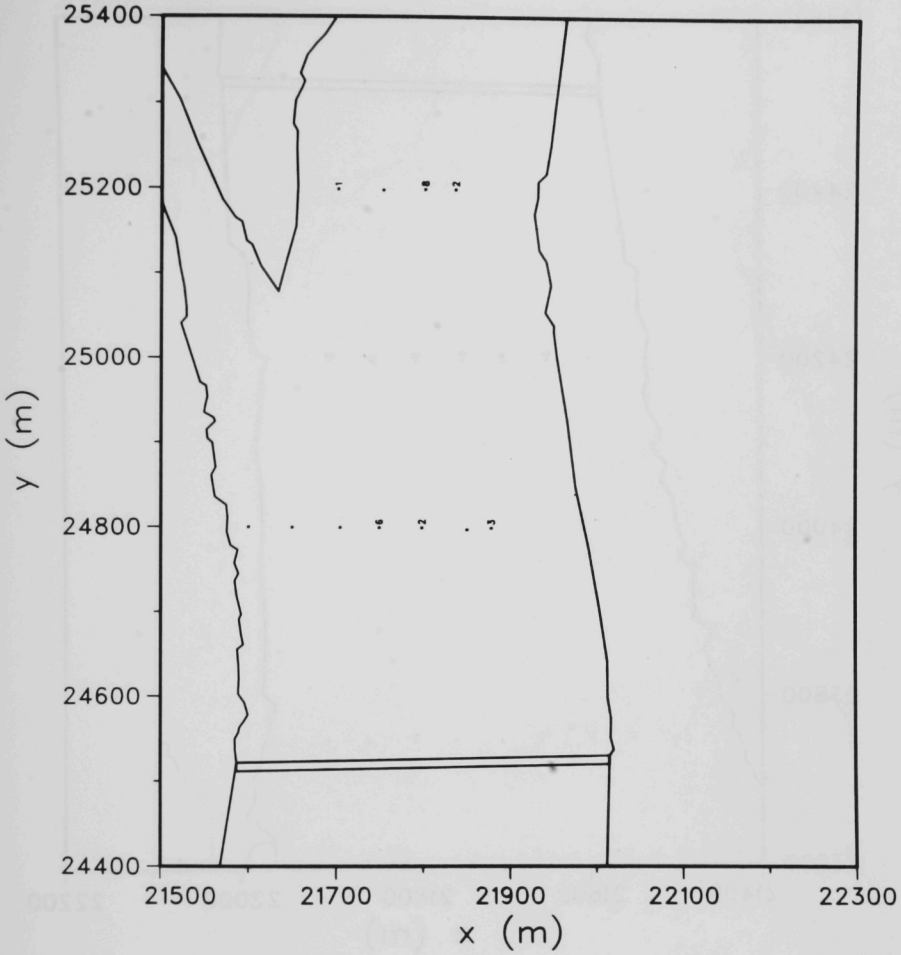

FIGURE A.26 Bottom Sampling Locations and Dyed Sand Counts in Region b of the Savanna Bay Site for Survey IV

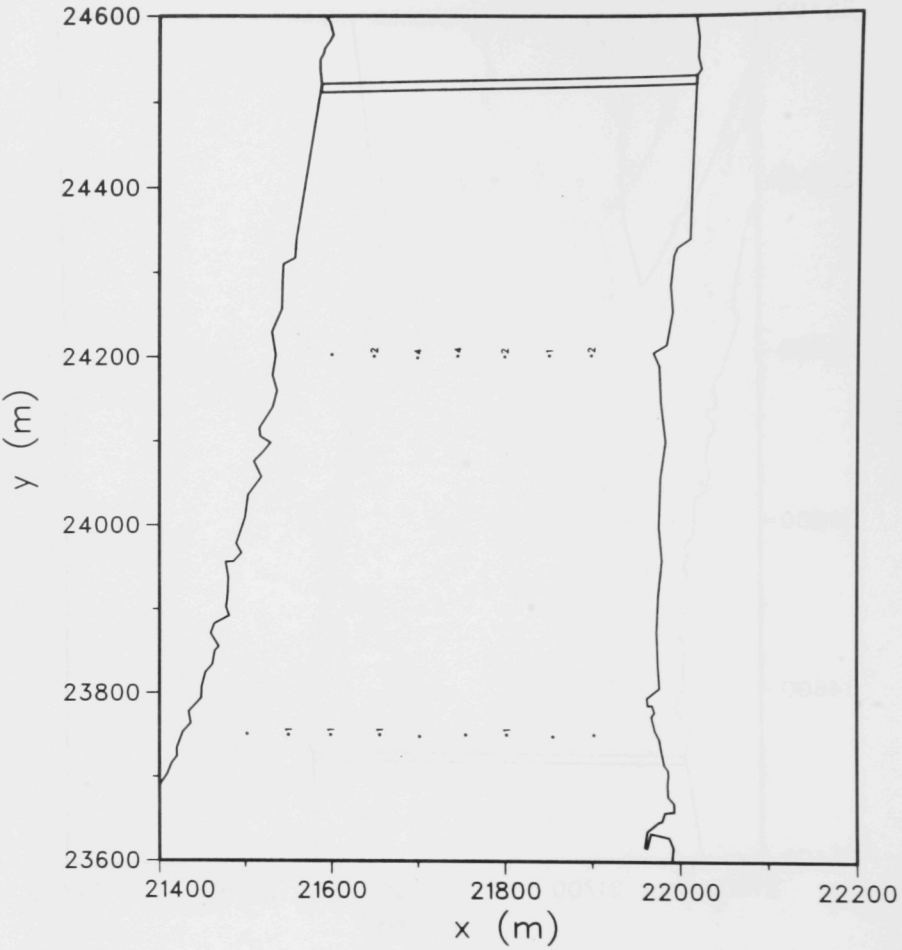

FIGURE A.27 Bottom Sampling Locations and Dyed Sand Counts in Region c of the Savanna Bay Site for Survey IV

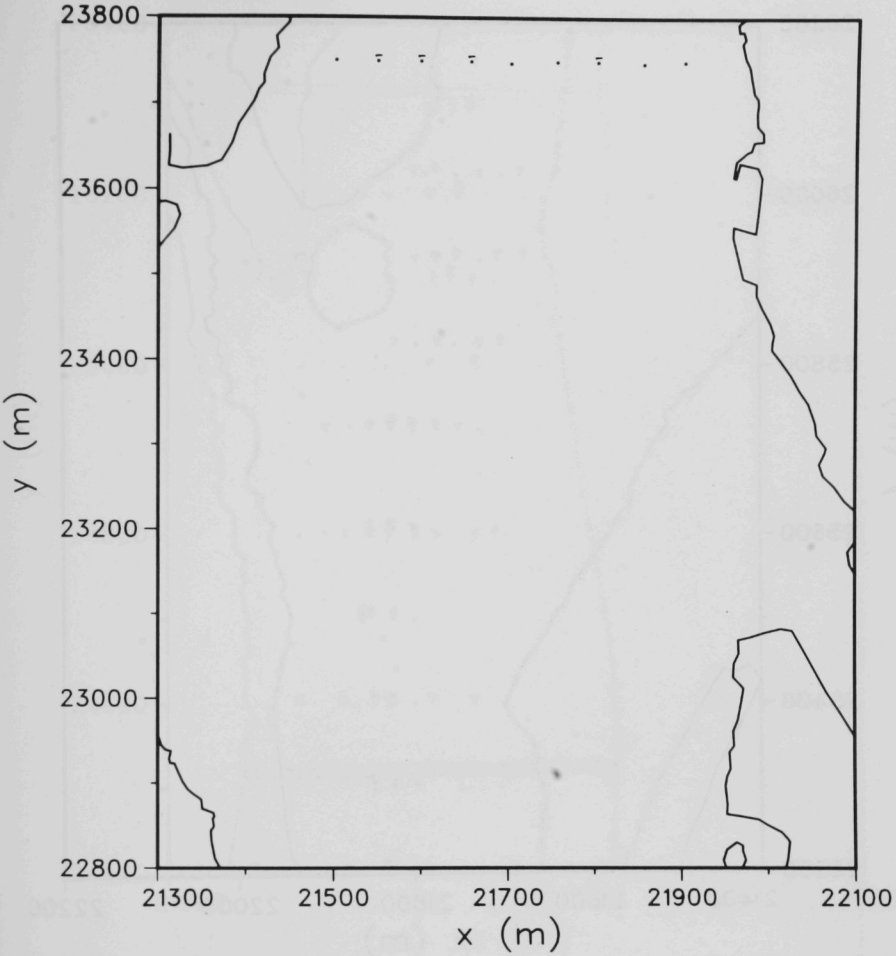

FIGURE A.28 Bottom Sampling Locations and Dyed Sand Counts in Region d of the Savanna Bay Site for Survey IV

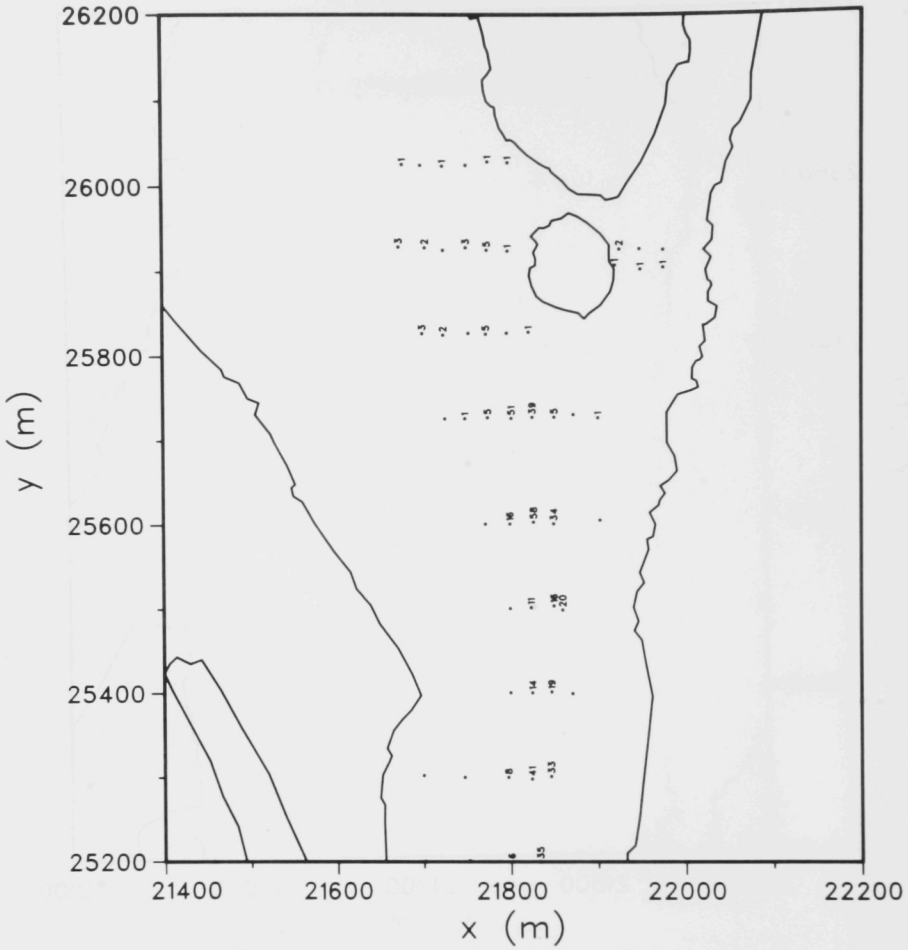

FIGURE A.29 Bottom Sampling Locations and Dyed Sand Counts in Region a of the Savanna Bay Site for Survey V

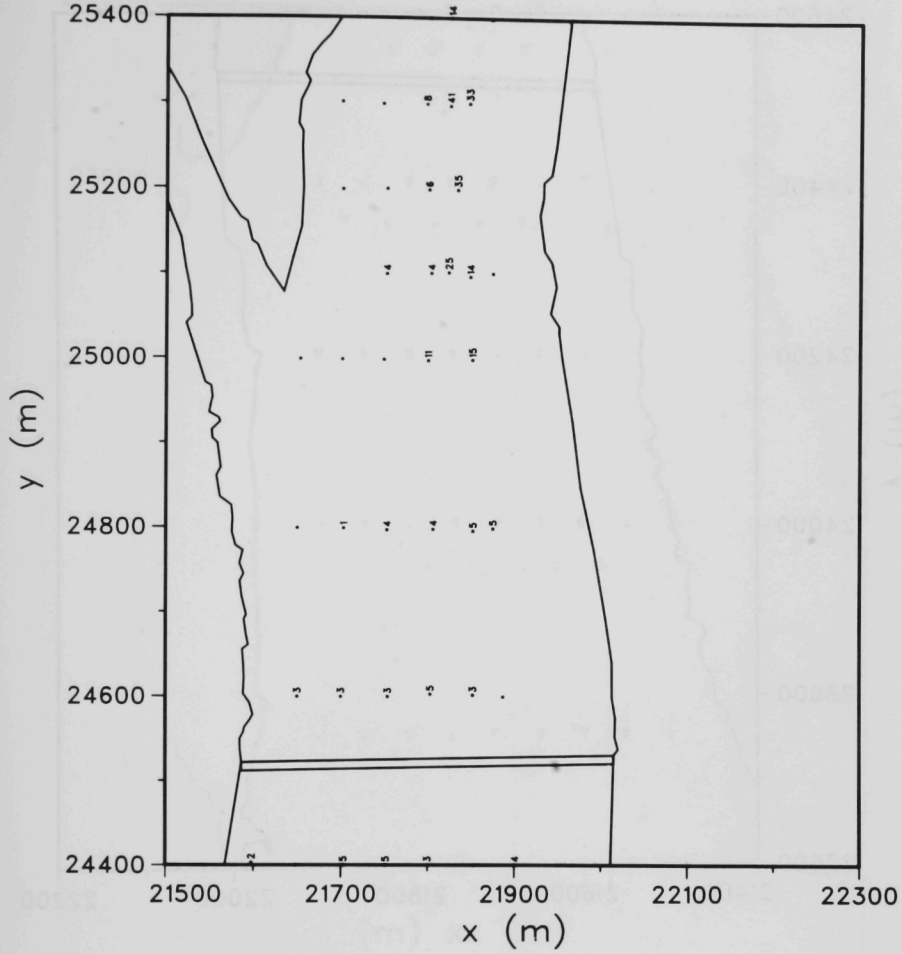

FIGURE A.30 Bottom Sampling Locations and Dyed Sand Counts in Region b of the Savanna Bay Site for Survey V

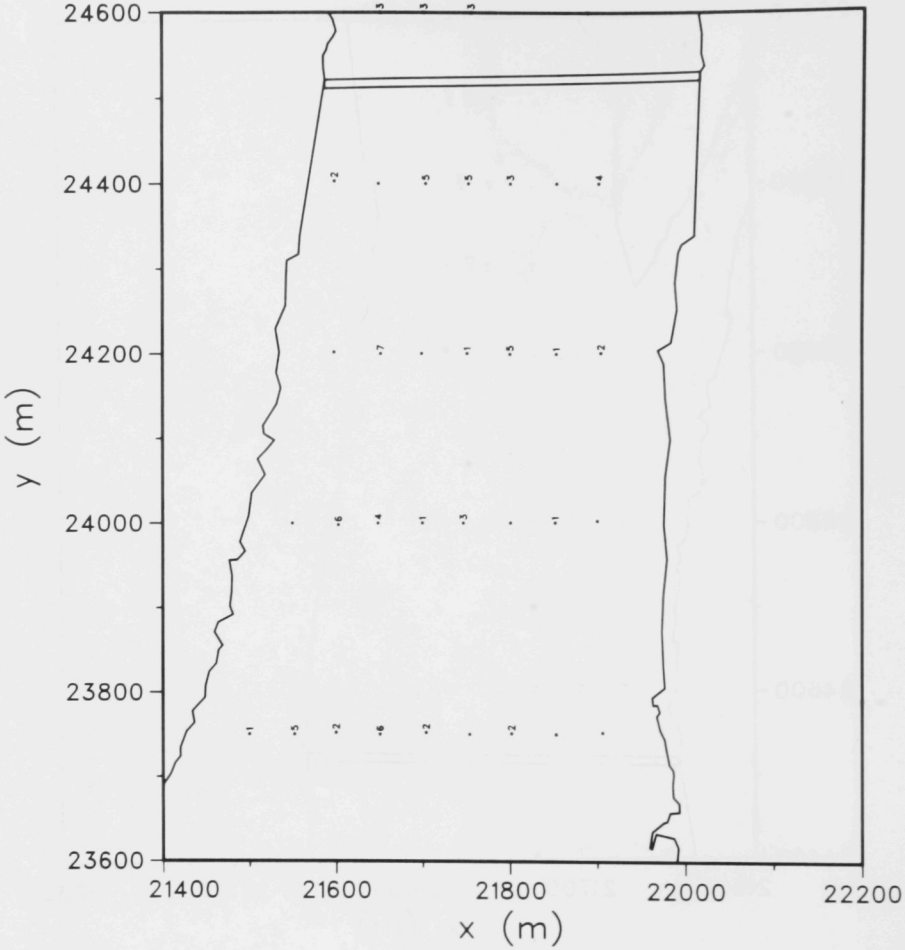

FIGURE A.31 Bottom Sampling Locations and Dyed Sand Counts in Region c of the Savanna Bay Site for Survey V

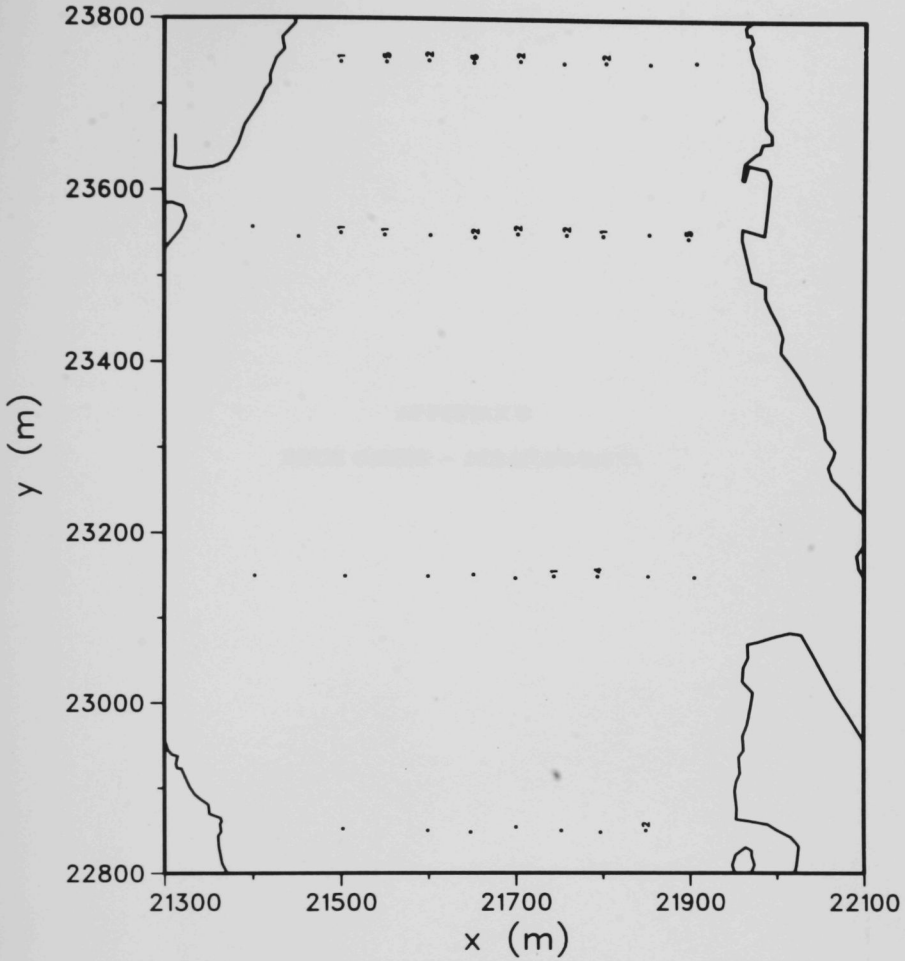

FIGURE A.32 Bottom Sampling Locations and Dyed Sand Counts in Region d of the Savanna Bay Site for Survey V

APPENDIX B

DUCK CREEK — DETAILED DATA

APPENDIX B

DUCK CREEK — DETAILED DATA

Results of the six bathymetric surveys at the Duck Creek site, along with some of the supporting data, were presented in Sec. 4. The complete sets of bathymetric data from each of these surveys are given in Figs. B.1-B.12. The approximate boat paths for each survey are shown in the upper left-hand quadrant. The bottom profiles for the transverse transects are then presented in sequence, starting in the upper right-hand quadrant with the transect farthest upstream and proceeding downstream. The profiles for the individual transects start from the Iowa (west) end of each transect. The bottom profiles for the longitudinal transects, which are approximately parallel to the thalweg, are then presented in sequence, starting with the transect closest to the Illinois (east) shore and proceeding toward the Iowa (west) shore. The profiles for the individual transects start from the downstream end of each transect.

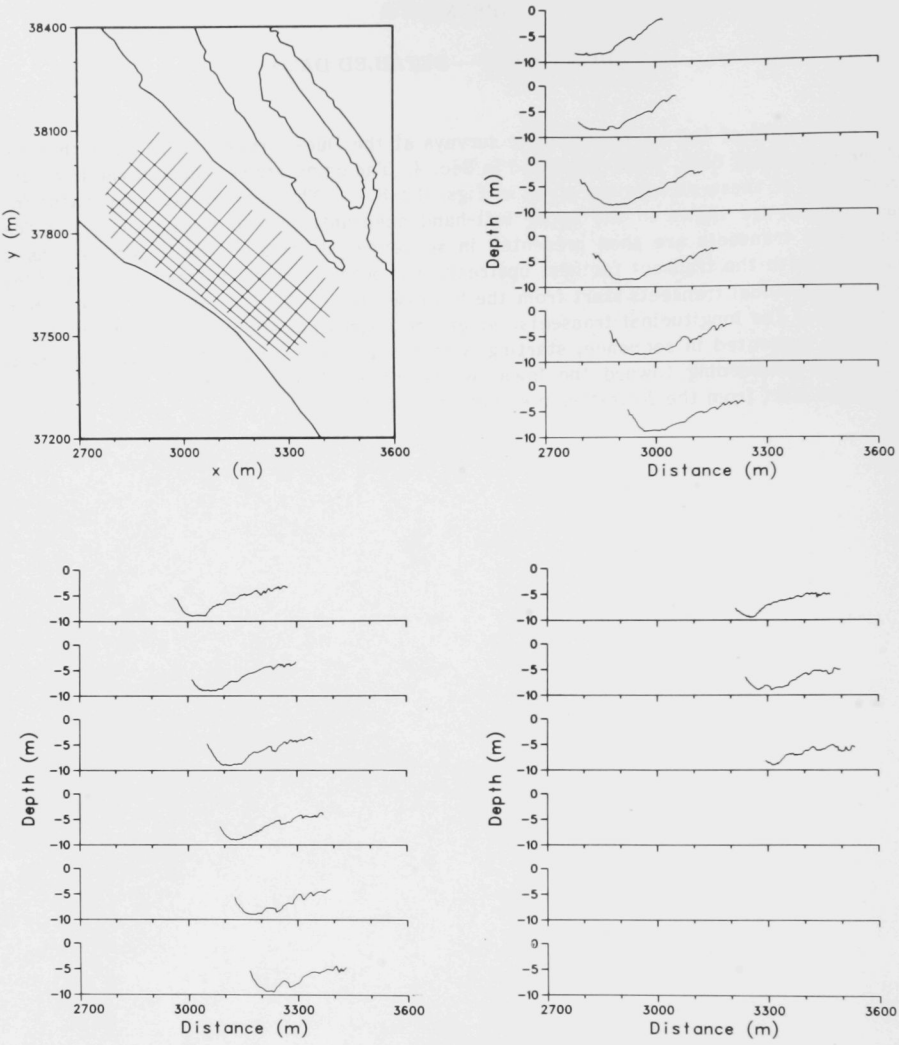

FIGURE B.1 Bathymetric Transects and Transverse Bottom Profiles for the Predisposal Survey at Duck Creek on October 24, 1983

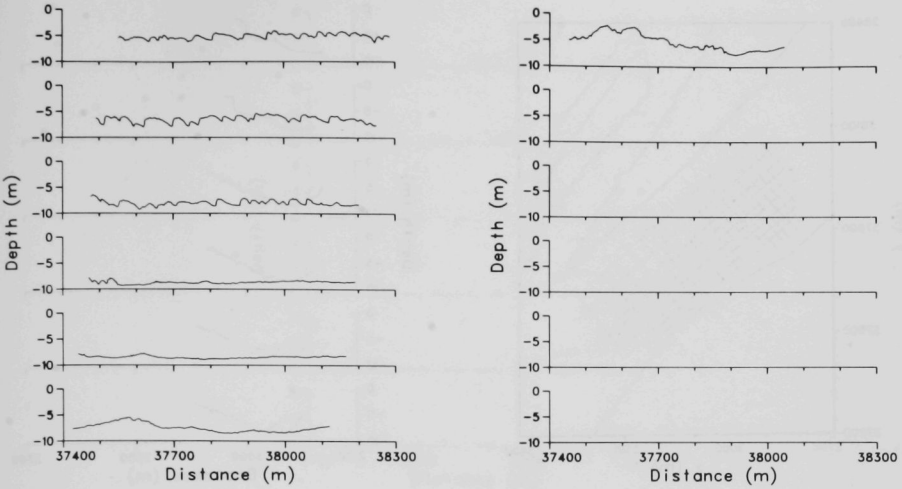

FIGURE B.2 Longitudinal Bottom Profiles for the Predisposal Survey at Duck Creek on October 24, 1983

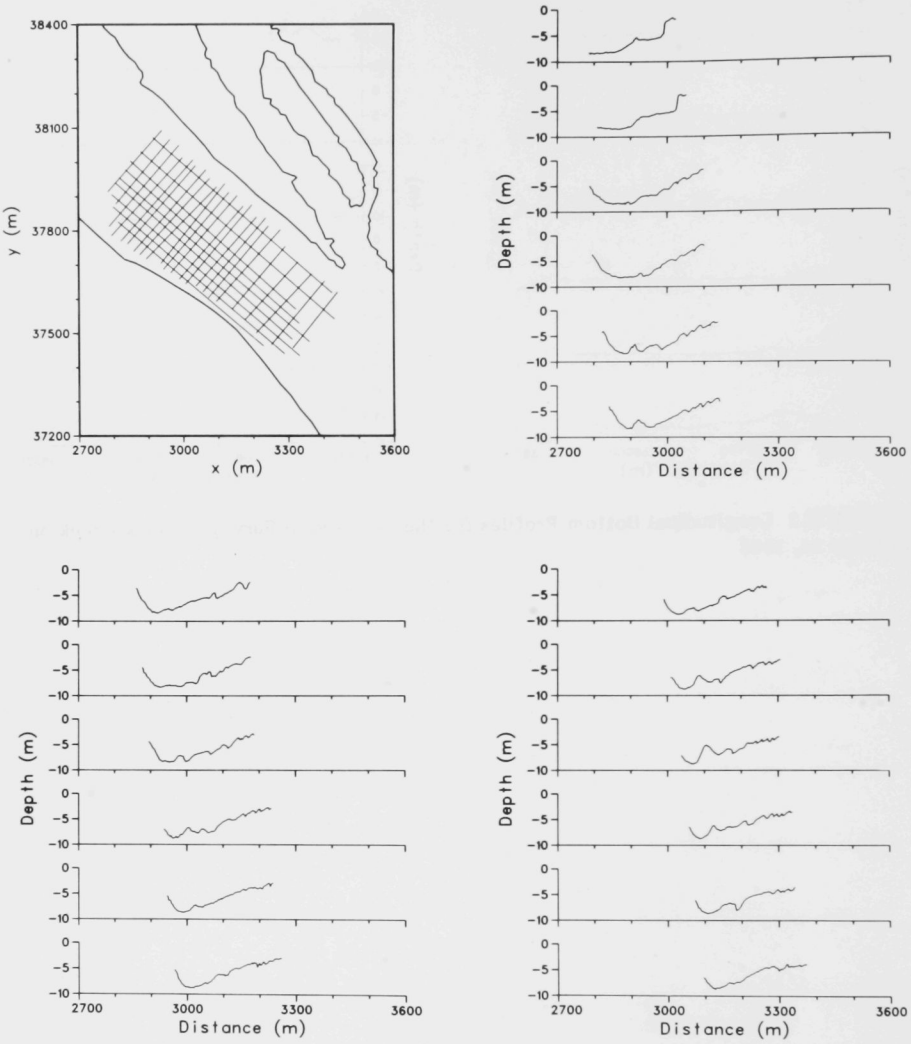

FIGURE B.3 Bathymetric Transects and Transverse Bottom Profiles for Survey I at Duck Creek on October 29, 1983

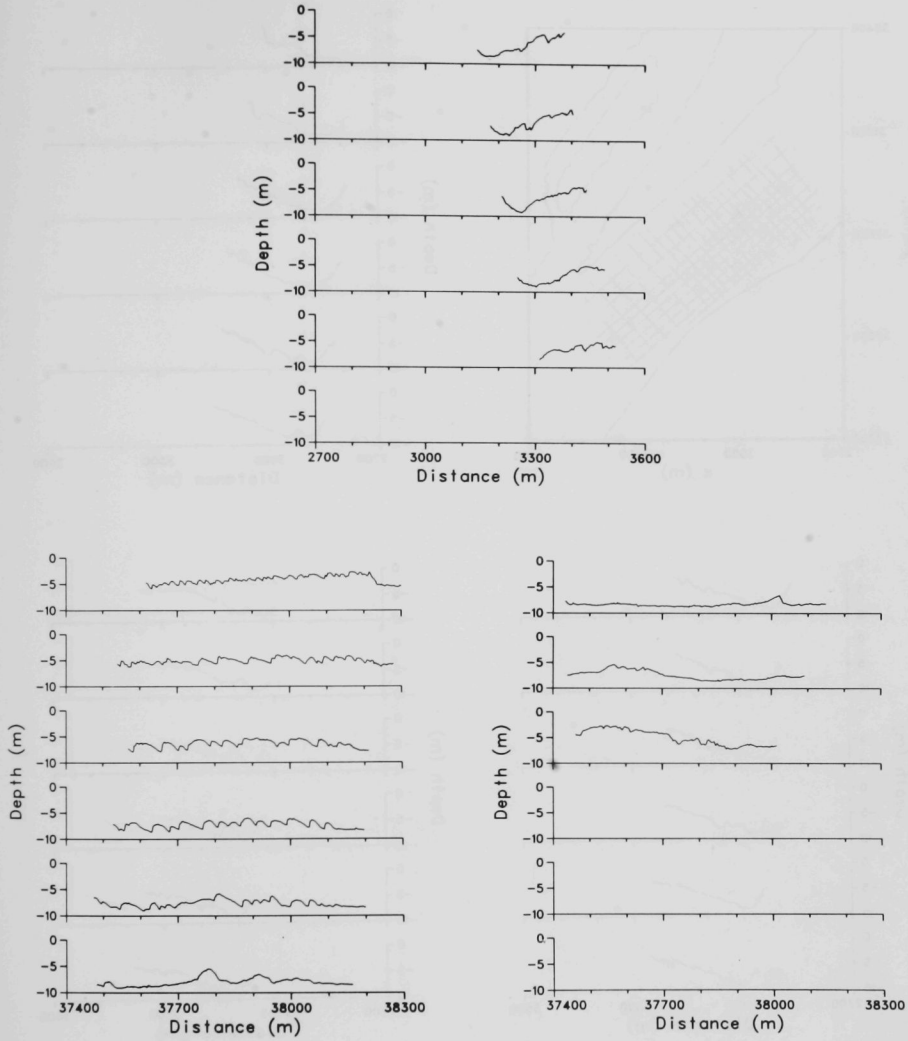

FIGURE B.4 Transverse and Longitudinal Bottom Profiles for Survey I at Duck Creek on October 29, 1983

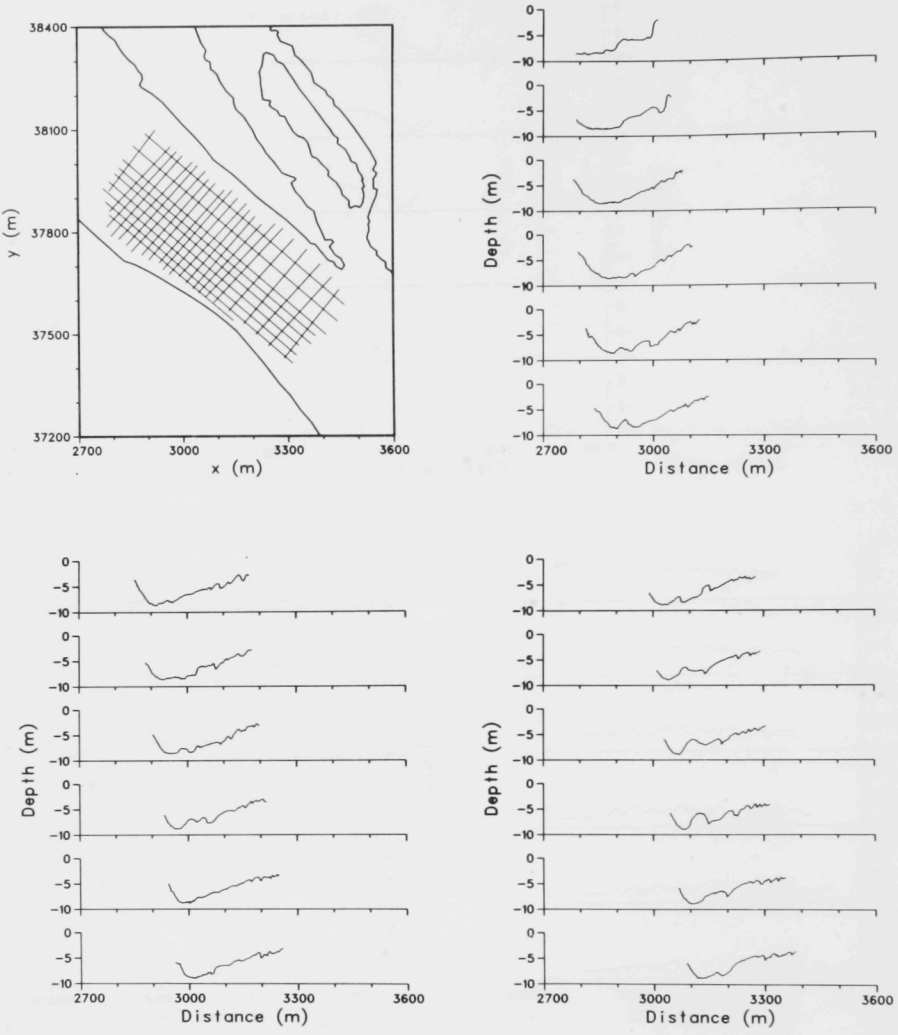

FIGURE B.5 Bathymetric Transects and Transverse Bottom Profiles for Survey II at Duck Creek on November 10, 1983

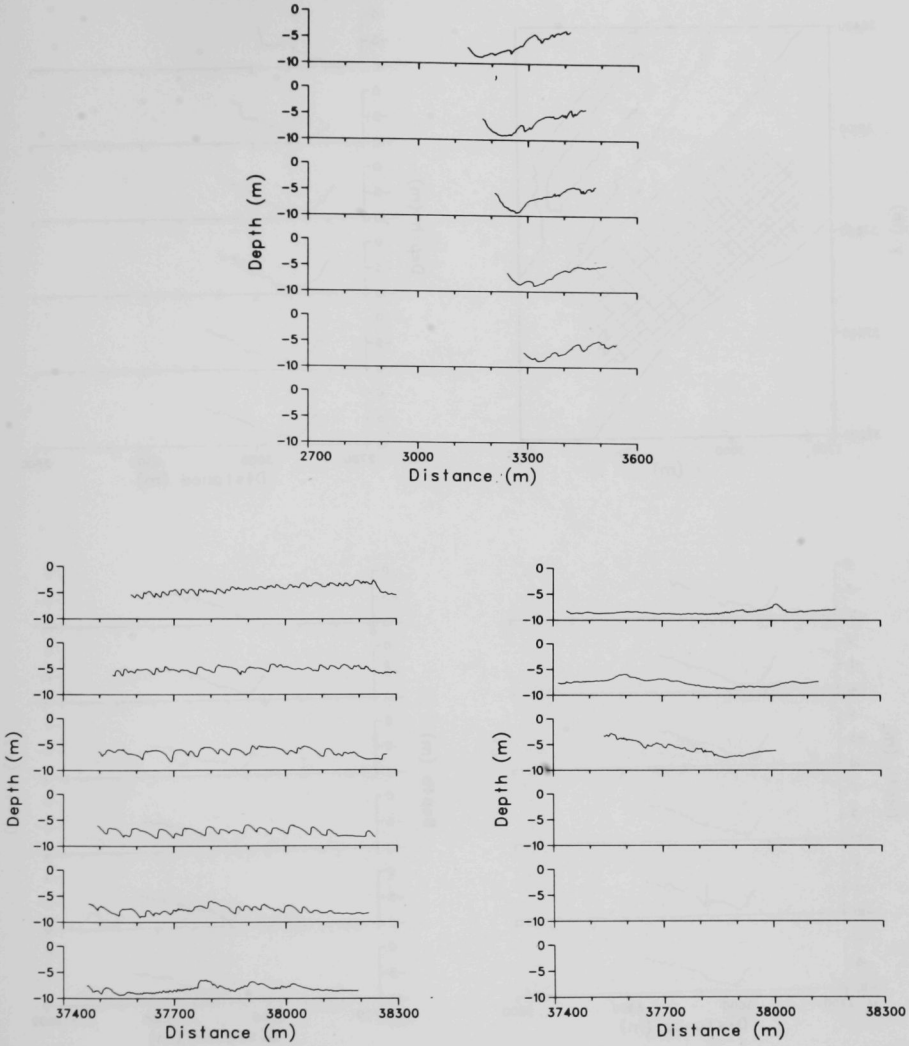

FIGURE B.6 Transverse and Longitudinal Bottom Profiles for Survey II at Duck Creek on November 10, 1983

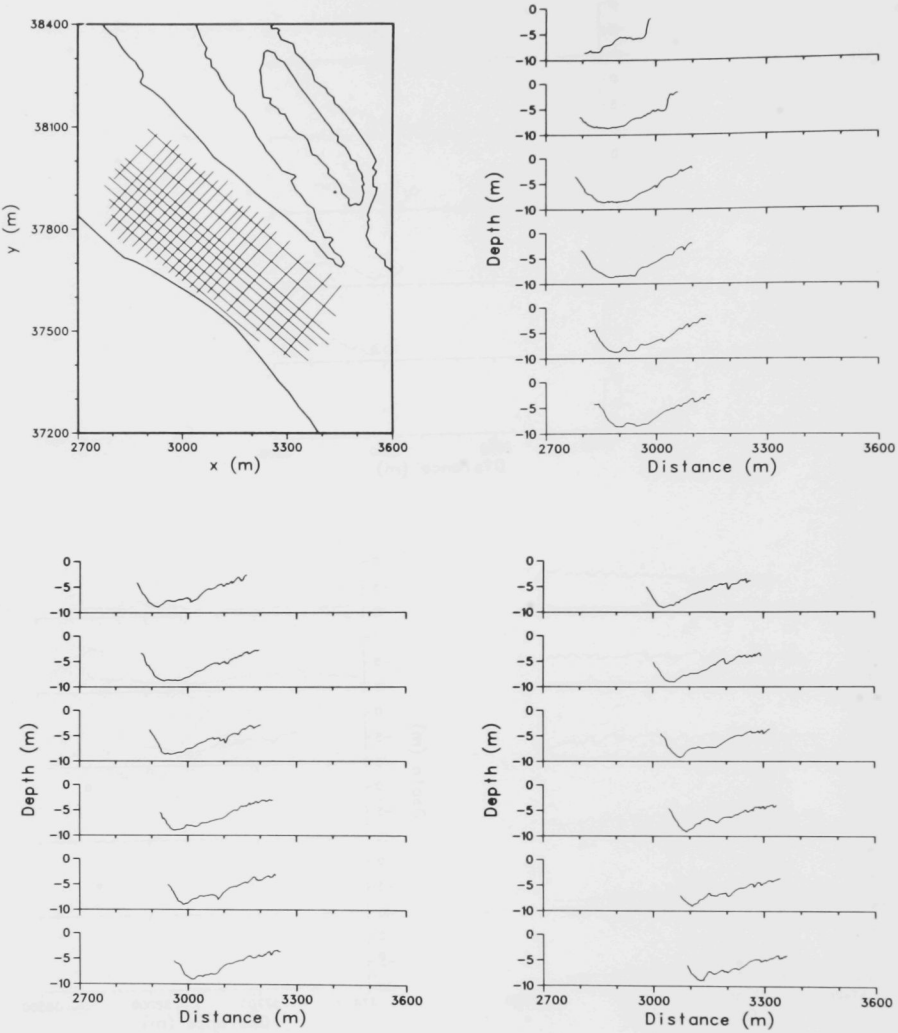

FIGURE B.7 Bathymetric Transects and Transverse Bottom Profiles for Survey III at Duck Creek on December 14, 1983

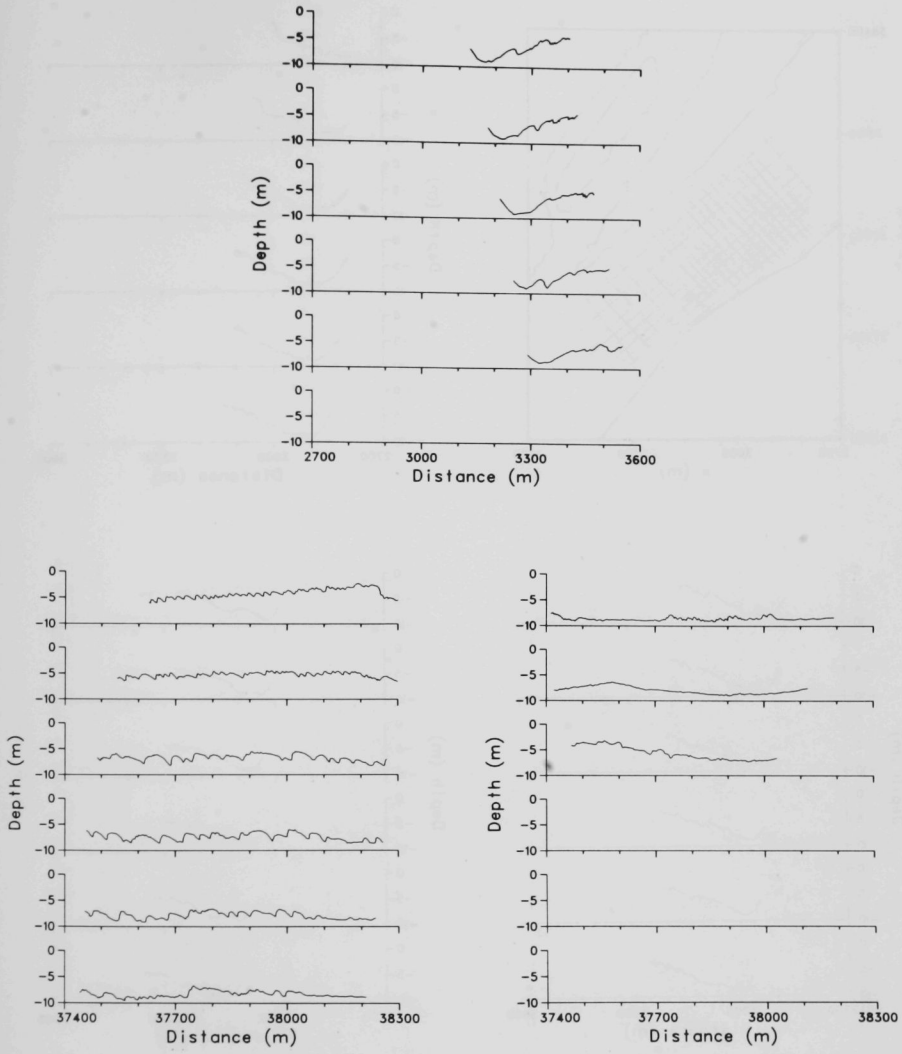

FIGURE B.8 Transverse and Longitudinal Bottom Profiles for Survey III at Duck Creek on December 14, 1983

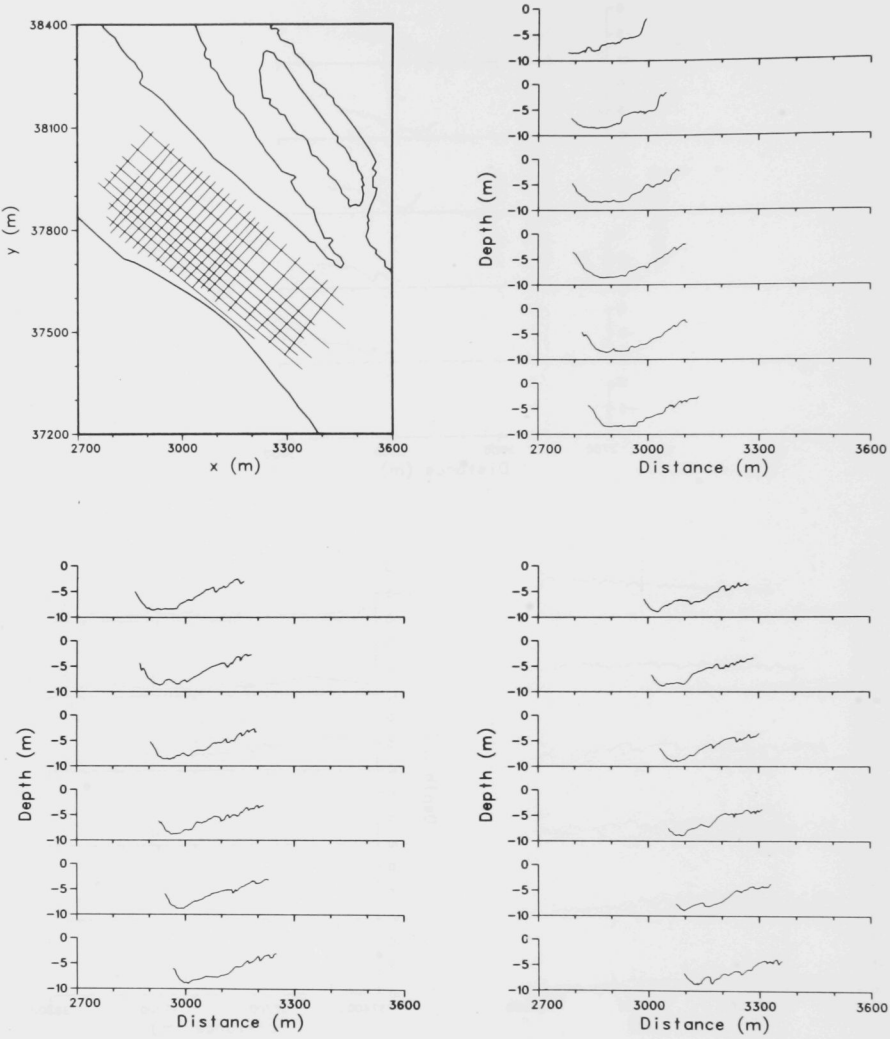

FIGURE B.9 Bathymetric Transects and Transverse Bottom Profiles for Survey IV at Duck Creek on March 27, 1984

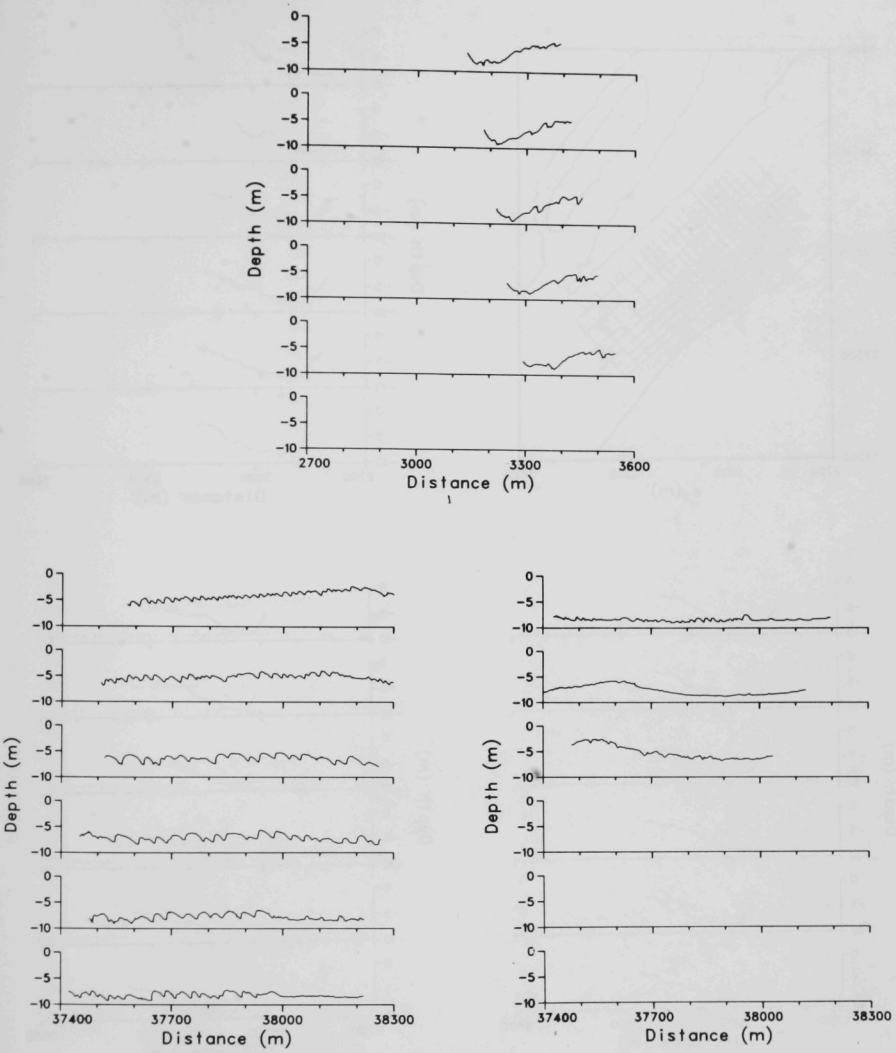

FIGURE B.10 Transverse and Longitudinal Bottom Profiles for Survey IV at Duck Creek on March 27, 1984

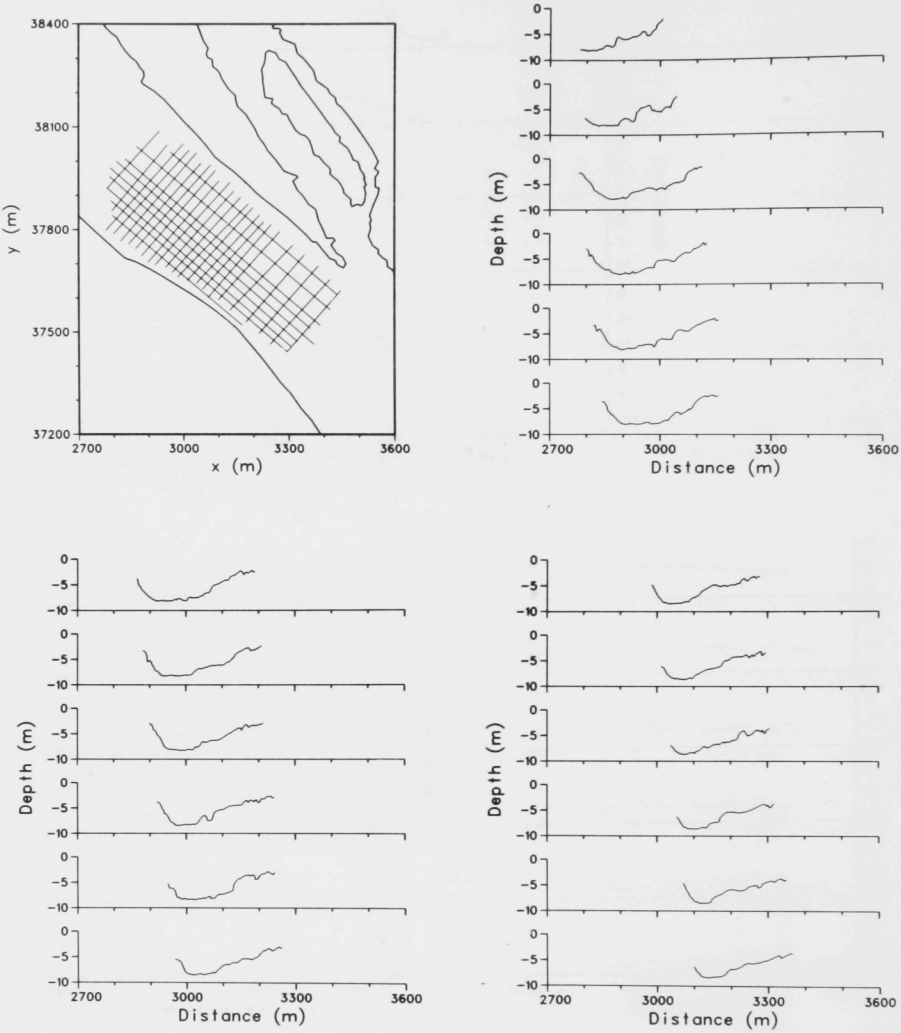

FIGURE B.11 Bathymetric Transects and Transverse Bottom Profiles for Survey V at Duck Creek on August 2, 1984

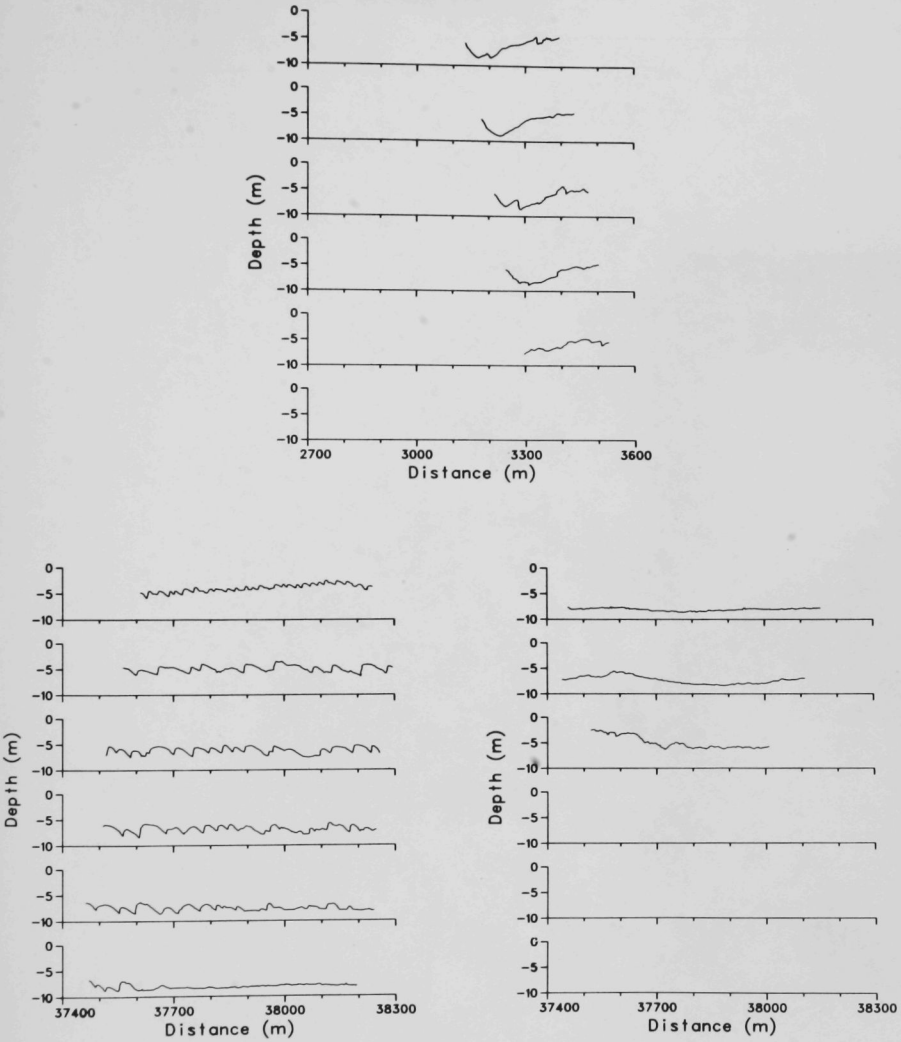

FIGURE B.12 Transverse and Longitudinal Bottom Profiles for Survey V at Duck Creek on August 2, 1984

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